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Determination of the Errors in Evaluated Data with Allowance for Correlations. Evaluation of $\sigma_f(^{235}U)$, $\alpha(^{235}U)$, $\alpha(^{239}Pu)$ and $\sigma_f(^{239}Pu)$ for the Evaluated Nuclear Data Library BOYaD-3

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DETERMINATION OF THE ERRORS IN EVALUATED DATA WITH ALLOWANCE FOR CORRELATIONS. EVALUATION OF $\sigma_f(^{235}U)$, $\alpha(^{235}U)$, $\alpha(^{239}Pu)$ and $\sigma_f(^{239}Pu)$ FOR THE EVALUATED NUCLEAR DATA LIBRARY BOYaD-3

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ABSTRACT

The authors have developed a method of evaluating data and the errors in them with allowance for correlations between the partial errors of different experiments. This method has been used to evaluate the values of $\sigma_f(^{235}U)$, $\alpha(^{235}U)$ and $\alpha(^{239}Pu)$ needed for establishing an evaluated nuclear data library.

1. CONSIDERATION OF CORRELATIONS IN DETERMINING THE ERRORS IN EVALUATED DATA

In obtaining evaluated nuclear data it is important not only to have the data but also to assign realistic errors to them. Such information will enable us to evaluate the errors in calculated reactor functionals and - what is no less important - to refine differential data by means of integral experiments.

However, one of the least thoroughly treated problems is that of determining the errors in evaluated data and of specifically determining the "weights" of the experimental points used in the evaluation.

If different values of the measured quantities σ_i are obtained with different degrees of accuracy, characterized by the root-mean-square error $\Delta\sigma_i$, the most probable value is the weighted mean

$$\bar{\sigma} = \frac{\sum_i \frac{\sigma_i}{\Delta\sigma_i^2}}{\sum_i \frac{1}{\Delta\sigma_i^2}}$$

However, the use of "weights" inversely proportional to the squares of the errors in the experimental data is valid only if there are no correlations between the errors. In fact, however, the errors in experimental data are often strongly correlated because of the use of identical measurement methods. It is obvious that the true error in evaluated data can be found only when detailed information is available on the correlation properties of the errors from the different experiments used in the evaluation. The method developed below is based on the use of such information and on the general methods of mathematical statistics [1].

Let there be N measurements of the quantity σ_o (the unknown true value of the quantity being measured) which are equal to σ_i ($i = 1 \ldots N$). The result of each individual measurement of σ_i is a functional of some set of actually measured quantities f_{ik} ($k = 1, \ldots\ldots M$) with error Δf_{ik}, where M is the total number of parameters needed to obtain σ_i.

Then, confining ourselves to a linear approximation, we obtain

$$\sigma_i = \sigma_o + \sum_{k=1}^{M} \frac{\partial\sigma_i}{\partial f_{ik}} \Delta f_{ik} \quad . \tag{1.1}$$

The quantity $\frac{\partial\sigma_i}{\partial f_{ik}} \Delta f_{ik}$ is part of the error in the i-th experiment, due to uncertain knowledge of the k-th parameter being measured (denoted below as $\Delta\sigma_{ik}$).

Let the evaluated value now be obtained by averaging the experimental quantities taken with "weights" a_i^2 such that

$$\sum_{i=1}^{N} a_i^2 = 1 \ .$$

Then

$$\sigma_{ev.} = \sum_{i=1}^{N} \sigma_i a_i^2 \quad . \tag{1.2}$$

Summing Eq. (1.1) in i, we obtain

$$\sum_{i=1}^{N} \sigma_i a_i^2 = \sum_{i=1}^{N} \sigma_o a_i^2 + \sum_{i=1}^{N} \sum_{k=1}^{M} \Delta\sigma_{ik} a_i^2 \tag{1.3}$$

Then

$$\overline{|\sigma_{ev.} - \sigma_o|^2} = \overline{\left|\sum_{i=1}^{N}\sum_{k=1}^{M}\Delta\sigma_{ik}a_i^2\right|^2} = \sum_{i=1}^{N}\sum_{k=1}^{M}\sum_{j=1}^{N}\sum_{m=1}^{M}a_i^2a_j^2\overline{\Delta\sigma_{ik}\Delta\sigma_{jm}} =$$

$$= \sum_{i=1}^{N}\sum_{k=1}^{M}\sum_{j=1}^{N}\sum_{m=1}^{M}a_i^2a_j^2K_{ikjm}\sqrt{\overline{|\Delta\sigma_{jk}|^2}}\cdot\sqrt{\overline{|\Delta\sigma_{jm}|^2}} \tag{1.4}$$

where K_{ikjm} is a correlation coefficient determined by the relation

$$K_{ikjm} = \frac{\overline{\Delta\sigma_{ik}\cdot\Delta\sigma_{jm}}}{\sqrt{\overline{|\Delta\sigma_{ik}|^2}}\sqrt{\overline{|\Delta\sigma_{jm}|^2}}} \tag{1.5}$$

Formula (1.4) gives the error in the evaluated value through the root-mean-square deviation of the partial measurement errors, $\sqrt{\overline{|\Delta\sigma_{ik}|^2}}$ the coefficient of correlation between these partial errors, K_{ikjm}, and the "weights" used in the evaluation, a_i^2.

It seems natural to use the dispersion of an evaluation as the criterion of its acceptability, i.e. to require that evaluated quantities should have minimum dispersion boundaries. It has been established [2] that under sufficiently general conditions there is a lower dispersion boundary for evaluations. For this purpose, the only requirement is that the function should be doubly-differentiable with respect to the distribution parameter being sought.

We shall show that when correlations are totally absent, this method is equivalent to the method of least squares with "weights" inversely proportional to the square of the error.

In this case $K_{ikjm} = \sigma_{ikjm}$, where σ_{ikjm} is the four-dimensional Kronecker symbol, and expression (1.4) takes the form

$$\overline{|\sigma_{ev.} - \sigma_o|^2} = \sum_{i=1}^{N}a_i^4\sum_{k=1}^{M}\overline{|\Delta\sigma_{ik}|^2}$$

and $\sum_{k=1}^{M}\overline{|\Delta\sigma_{ik}|^2} = \overline{|\Delta\sigma_i|^2}$ is the RMS error of the i-th measurement.

Then

$$\overline{|\sigma_{ev.}-\sigma_o|^2} = \sum_{i=1}^{N} a_i^4\,\overline{|\Delta\sigma_i|^2} \tag{1.6}$$

The values of a_i^2 minimizing $\overline{|\sigma_{ev.}-\sigma_o|^2}$ can be found from the condition

$$\begin{cases} \dfrac{\partial(\overline{|\sigma_{ev.}-\sigma_o|^2})}{\partial a_n^2} = 0 \;, \quad n \neq 1 \\ \sum\limits_{i=1}^{N} a_i^2 = 1 \end{cases} \tag{1.7}$$

Let us now convert expression (1.6), taking out the first experiment, to the form

$$\overline{|\sigma_{ev.}-\sigma_o|^2} = \sum_{i\neq 1} a_i^4\,\overline{|\Delta\sigma_i|^2} + a_1^4\,\overline{|\Delta\sigma_1|^2}$$

and substitute $a_1^2 = 1 - \sum\limits_{i\neq 1} a_i^2$
Then

$$\overline{|\sigma_{ev.}-\sigma_o|^2} = \sum_{i\neq 1} a_i^4\,\overline{|\Delta\sigma_i|^2} + \sum_{i\neq 1}\sum_{m\neq 1} a_i^2 a_m^2\,\overline{|\Delta\sigma_1|^2} - - 2\sum_{i\neq 1} a_i^2\,\overline{|\Delta\sigma_1|^2} + \overline{|\Delta\sigma_1|^2} \;. \tag{1.8}$$

Differentiating Eq. (1.8) with respect to a_n^2, $n = 1, \dots N$ $(n \neq 1)$, we obtain $(N - 1)$ equations of the form

$$\frac{\partial\overline{|\sigma_{ev.}-\sigma_o|^2}}{\partial a^2_{n(n\neq 1)}} = 2a_n^2\,\overline{|\Delta\sigma_n|^2} - 2\,\overline{|\Delta\sigma_1|^2} + 2\sum_{i\neq 1} a_i^2\,\overline{|\Delta\sigma_1|^2} = 0$$

or

$$a_n^2\,\overline{|\Delta\sigma_n|^2} = (1 - \sum_{i\neq 1} a_i^2)\,\overline{|\Delta\sigma_1|^2} \;,$$

from which, using $1 - \sum\limits_{i\neq 1} a_i^2 = a_1^2$, we obtain

$$a_n^2\,\overline{|\Delta\sigma_n|^2} = a_1^2\,\overline{|\Delta\sigma_1|^2} \;, \quad \text{i.e.} \quad \frac{a_n^2}{a_1^2} = \frac{\overline{|\Delta\sigma_1|^2}}{\overline{|\Delta\sigma_n|^2}}$$

Thus, in the absence of correlations between the errors of experiments, the "weights" are inversely proportional to the square of the errors.

Let us consider that the total error can be so finely divided into partial errors that $K_{ikjm} = 0$ for $k \neq m$. This assumption means that the errors in any two different parameters required to obtain a cross-section do not correlate with each other. Using the notation $K_{kij} = K_{ikjk}$, we can rewrite formula (1.4) as

$$\overline{|\sigma_{ev.} - \sigma_o|^2} = \sum_{i=1}^{N} \sum_{k=1}^{M} \sum_{j=1}^{N} a_i^2 a_j^2 K_{kij} \sqrt{\overline{|\Delta\sigma_{ik}|^2}} \cdot \sqrt{\overline{|\Delta\sigma_{jk}|^2}} \; . \tag{1.9}$$

If correlations exist, the system in expression (1.7) becomes a system of (N - 1) linear equations:

$$\frac{\partial \overline{|\sigma_{ev.} - \sigma_o|^2}}{\partial a_{n(n\neq 1)}^2} = 2 \sum_{k=1}^{M} \sum_{i\neq 1}^{N} a_i^2 \Big(K_{kin} \sqrt{\overline{|\Delta\sigma_{ik}|^2}} \cdot \sqrt{\overline{|\Delta\sigma_{nk}|^2}} - K_{ki1} \sqrt{\overline{|\Delta\sigma_{ik}|^2}} \times$$

$$\times \sqrt{\overline{|\Delta\sigma_{1k}|^2}} - K_{k1n} \sqrt{\overline{|\Delta\sigma_{1k}|^2}} \cdot \sqrt{\overline{|\Delta\sigma_{nk}|^2}} - K_{k11} \sqrt{\overline{|\Delta\sigma_{1k}|^2}} \cdot \sqrt{\overline{|\Delta\sigma_{1k}|^2}} \Big) +$$

$$+ \sum_{k=1}^{M} \Big(K_{kn1} \sqrt{\overline{|\Delta\sigma_{nk}|^2}} \cdot \sqrt{\overline{|\Delta\sigma_{1k}|^2}} - K_{k11} \sqrt{\overline{|\Delta\sigma_{1k}|^2}} \cdot \sqrt{\overline{|\Delta\sigma_{1k}|^2}} \Big) = 0 \; .$$

Formula (1.9) gives the error in the evaluated value for an individual point on the curve. We define the correlation coefficient for the errors of any two evaluated points n and m as

$$B_{nm} = \frac{\overline{\Delta\sigma_n \cdot \Delta\sigma_m}}{\sqrt{\overline{|\Delta\sigma_n|^2}} \cdot \sqrt{\overline{|\Delta\sigma_m|^2}}} \; , \tag{1.10}$$

where the subscripts n and m denote the numbers of the points for which the correlation coefficient is calculated, and $\Delta\sigma_n$ and $\Delta\sigma_m$ are the errors in the evaluated values at these points. They are defined as

$$\Delta\sigma_n = \sum_{i=1}^{N} \sum_{k=1}^{M} \Delta\sigma_{ikn} a_{in}^2 \quad \text{and} \quad \Delta\sigma_m = \sum_{j=1}^{N} \sum_{k=1}^{M} \Delta\sigma_{jkm} a_{jm}^2 \; ,$$

where a^2_{jm} is the "weight" of the j-th experiment when it is used in the evaluation at point m and $\Delta\sigma_{jkm}$ the k-th partial error of the j-th experiment at point m. If we define the correlation coefficient as

$$K_{kinjm} = \frac{\overline{\Delta\sigma_{jkm}\cdot\Delta\sigma_{ikn}}}{\sqrt{\overline{|\Delta\sigma_{ikn}|^2}}\cdot\sqrt{\overline{|\Delta\sigma_{jkm}|^2}}}$$

and assume, as before, that errors of the same nature correlate and that the partial errors of a given experiment are independent, then the coefficient of correlation between the points of the cross-section energy dependence curve will be defined by the expression

$$B_{nm} = \frac{\sum_{k=1}^{M}\sum_{i=1}^{N}\sum_{j=1}^{N} a^2_{in}a^2_{jm}K_{kinjm}\sqrt{\overline{|\Delta\sigma_{ikn}|^2}}\cdot\sqrt{\overline{|\Delta\sigma_{jkm}|^2}}}{\sqrt{\overline{|\Delta\sigma_n|^2}}\cdot\sqrt{\overline{|\Delta\sigma_m|^2}}} \tag{1.11}$$

Thus, the coefficient of correlation between the errors of two evaluated points is expressed in terms of the values of the partial errors of the experiments used in the evaluation, the "weights" which these experiments were assigned in the evaluation and the correlation coefficients of the partial errors at these points.

In the calculations the correlation coefficient K_{kinjm} was taken to be independent of n and m, i.e. $K_{kinjm} = K_{kji}$. In fact, if the correlation coefficient for the partial errors depends on a point (for example, if some parameter required for cross-section determination is measured differently at different points), then we can formally assume that different studies are involved, and the dependence of the correlation coefficient for different points should be converted to one for different studies.

The algorithm described here was used in a computer program which employs the partial errors and the correlations between them as a basis for determining, by the iteration method, the "weights" of the experimental data which will minimize the error in the evaluated value, the errors in the evaluated values at different points and the coefficients of correlation between them.

The present method was used in evaluating the fission cross-section $\sigma_f(^{235}U)$ in the 0.1 keV-20 MeV region, $\alpha(^{235}U)$ in the 0.1-1000 keV region, $\alpha(^{239}Pu)$ in the 0.1-1000 keV region and $\sigma_f(^{239}Pu)$ in the 0.1 keV-10 MeV region. It has also been used to obtain correlation coefficient matrices for correlations between the errors in group constants for $\sigma_f(^{235}U)$, $\sigma_f(^{239}Pu)$, $\alpha(^{235}U)$ and $\alpha(^{239}Pu)$.

2. EVALUATION OF THE FISSION CROSS-SECTION $\sigma f(^{235}U)$ IN THE 0.1 keV-20 MeV REGION WITH ALLOWANCE FOR CORRELATIONS BETWEEN THE ERRORS OF DIFFERENT EXPERIMENTS

The results of a number of $\sigma_f(^{235}U)$ measurements have been published in the last few years [3-5, 6, 7-13]. These studies differ from earlier work in using more up-to-date experimental procedures and in exhibiting smaller experimental errors. On the whole the new data give lower values of $\sigma_f(^{235}U)$ than those considered valid earlier. It was therefore necessary to perform a new evaluation of $\sigma_f(^{235}U)$, taking into account both the earlier results and the new ones. It was clear that special attention should be paid to the magnitude of the evaluation error in addition to the evaluation itself, the reason being that the errors of many experimental studies are quite strongly correlated through the use of similar measurement methods and standards. In the present study we therefore put forward the method described in the preceding section, which can be used to carry out a detailed analysis of the correlations between the errors in different experiments.

The $\sigma_f(^{235}U)$ evaluation was carried out in two energy regions - one from 100 eV to 100 keV, where the experimental data show a structure in the cross-section, and the other from 100 keV to 20 MeV, where the fission cross-section can be represented by a smooth curve.

The experimental data obtained in the thermal energy region must be renormalized in a uniform manner. Errors due to shifting of the energy scale and differences in energy resolution can be reduced to a minimum by normalizing over a wide energy interval. The 100 eV-1 keV region was chosen as such an interval.

The evaluation of $\sigma_f(^{235}U)$ in the region below 1 eV was carried out recently by Leonard [14], who obtained $\sigma_f = 583.54 \pm 1.7$ b at 0.0253 eV. This value agrees with that obtained by Lemmel [15]: $\sigma_f = 583.5 \pm 1.3$ b at 0.0253 eV.

Deruytter and Wagemans [16] have suggested that the value of the fission integral from 7.8 to 11 eV obtained by them be used for renormalization of experimental data. Leonard's analysis of these data [14] has shown that there is some systematic deviation of the data of Ref. [16] from the evaluated curve, which may be due to a change in the analyser channel width in this region. It may therefore not be advisable to normalize to these data alone. Fortunately, a number of other measurements have been made in the thermal region, viz. the data of Czirr and Sidhu [6], Gwin et al. [3], De Saussure et al. [17], Bowman et al. [18], Shore and Sailor [19], Michaudon et al. [20] and Van Shi-di et al. [21]. After renormalization of these data to $\sigma_f = 583.5$ b at 0.0253 eV, the fission integral from 7.8 to 11 eV was calculated: as the evaluated value Leonard [14] gives 241.24 ± 6.75 b.eV, which is the weighted mean of the data of Deruytter and Wagemans [16], Czirr and Sidhu [6], Gwin et al.[3] and De Saussure et al. [17]. The data of Bowman et al. [18] were used with only a one-third "weight" owing to the large deviation from other data; those of Shore and Sailor were not used because they were obtained only in the region up to 10 eV; and the reason for not using the data of Michaudon et al. [20] and Van Shi-di et al. [21] lay in the substantial difference in the shape of the curves and the systematic difference in the thermal region. We used 241.24 b.eV as the value of the fission integral from 7.8 to 11 eV for renormalizing data extending into the thermal region [17, 6, 3, 7, 22].

In the 0.1-1.0 keV region there are five series of experimental data which can be regarded as absolute data [17, 6, 3, 7, 22]. After correction of these data to the most recent value of the cross-sections for the $^{10}B(n,\alpha)$ and $^{6}Li(n,\alpha)$ reactions [23] and renormalization in the 7.8-11 eV region, we obtained a weighted mean value of 11 864 b.eV for the fission integral in the 0.1-1.0 keV region. The absolute data of Refs [24] and [25] need to be corrected for the angular distribution of alpha-particles from the $^{6}Li(n,\alpha)$ reaction, the correction being small at these energies. Consideration of the data of Refs [24] and [25] in obtaining the weighted mean value of the fission integral in the 0.1-1.0 keV region gave a value of 11883 ± 446 b.eV. Allowing for the error of renormalization in the eV region, the uncertainty in the most recent experimental data [6, 7, 22] is ~ 3.8%. The relative experimental data [20, 26, 27, 28, 21, 29, 5] were renormalized to the integral value of 11883 b.eV in the 0.1-1.0 keV region. The relative data of Refs [30, 4, 31] were renormalized in the 10-30 keV region to the mean fission integral in this region, 45 580 ± 2280 b.eV, obtained from the absolute data of Gwin et al. [3] and Czirr et al. [6].

In the 10-100 keV region the time-of-flight data of Gwin et al. [3] and Czirr et al. [6] and also measurements at individual points [32-34] agree on the whole to within ± 3%; in the 100-200 keV region the discrepancy goes up to 6% (for example the data of Refs [30] and [8]), while in the 200 keV-1 MeV region the bulk of the data [32-37, 8] are again in agreement to within ± 3%, except for the data of Refs [31] and [6]. The data of Czirr et al. [6] lie approximately 10% lower than those of Refs [35, 32, 8, 34]. A basic discrepancy of the order ± 5% is observed in the 250-300 keV region, where the recently obtained data of Wasson [31] on hydrogen are lower than most other measurements. There is also a disagreement in the 500-800 keV region both in form and in absolute magnitude between the data of Käppeler [38] and most other measurements.

In the energy region above 1 MeV the latest data [36, 37, 32, 8, 34, 33] agree on the whole to within ± 3%, although in the 1-1.3 MeV region the data of Barton et al. [36] are 4% higher than those of Refs [32, 8, 34], while at 5.4 MeV the data of White [33] are about 5% lower than the values of Barton et al. [36] and Czirr et al. [37]. The last discrepancy may be due to the fact that White did not make a correction for the angular distribution of protons from the (n,p) reaction, which can amount to ~ 2%. In particular, the ratio of the fission cross-sections at 14 MeV and 5.4 MeV measured by White is in conflict with the data obtained in other relative measurements [12, 37]. For this reason, in the evaluation the error of White's point at 5.4 MeV was increased by 5%.

In analysing the total errors in experimental measurements of σ_f, the following partial errors were distinguished:

k = 1 - in the determination of the number of ^{235}U nuclei;

k = 2 - in the extrapolation of the fragment spectrum to the zero discrimination level;

k = 3 - due to absorption of fragments in the layer;

k = 4 - due to scattering in the chamber walls, the backing of the layer and the target structure;

k = 5 - due to neutron attenuation in air;

k = 6 - in neutron flux determination;

k = 7 - in the background of the experiment;

k = 8 - in the efficiency of fission recording;

k = 9 - in the geometric factor;

k = 10 - in the cross-section of hydrogen (standard);

k = 11 - statistical;

k = 12 - in normalization.

The above division of the total error into partial components was based on the authors' own information concerning errors. Where such information was wanting (mainly old studies), the division was made by analysing the experimental method used and considering the errors inherent in that method.

Correlations were taken into account in the evaluation of $\sigma_f(^{235}U)$ by analysing the experimental methods included in the evaluation of the studies. The following correlations between experiments were found.

k = 1 (Determination of the number of ^{235}U nuclei)

In the study of Szabo (measurements in the 17 keV-1 MeV region) [35] and that of White (40 keV-14 MeV region) [33] the same layer of ^{235}U was used. These studies therefore correlate fully. A later analysis of Szabo's [32] differs from the papers mentioned above in that another layer was added to the one used in them. Thus Refs [35] and [32] correlate partially. Szabo's data in Ref. [8] do not differ at all in respect of this partial error from Ref. [35] and thus correlate fully.

We use the following rules to compile the table of correlations:

(a) If two studies independently correlate in full with a third study, then they fully correlate with each other. Consequently, Ref. [33] correlates fully with Ref. [8] and this is not in conflict with physical consideration of a given partial error. Partial correlations between Ref. [32] and Refs [33, 32, 8] follow at once from the rule;

(b) If one study [35] correlates partially with another [32] and fully with a third [33], then the second study [32] should also correlate partially with the third [33].

The partial correlations between Ref. [12] and Refs [33, 10, 11] with k = 0.3 were transferred to the given partial error from k = 12 (normalization error). This is due to the fact that we normalized Ref. [12] to the weighted mean from Refs [33, 10, 11], but these studies themselves have no partial error in the normalization since they are "absolute". In a case like this it is sometimes necessary to take into account a correlation between partial errors. Such an approach would greatly complicate our problem, however, especially when the supplementary correlation is superimposed on one already taken into account for a particular partial error. It is clearly impossible to treat the correlations additively in such a case.

The model we use to take correlations into account presupposes, as we have already said, that there are no correlations between partial errors, and this is true in most cases. In those few cases where a correlation between partial errors is introduced artificially (for example as a result of normalization), it can be considered in the partial error which makes the greatest contribution to the total error of the experiment. Such an approach does not violate our model and enables us to take fuller account of the existing correlations.

k = 2 (Extrapolation of the fragment spectrum to the zero discrimination level)

We may consider that in Refs [35, 33, 8] the error in the extrapolation of the fragment spectrum to the zero discrimination level is fully correlated because the same layer of material was used. Reference [35] in turn correlates partially with Ref. [32] since in the latter another layer was added to the one mentioned. The application of rule (b) thus requires that Ref. [32] should be partially correlated with Refs [33] and [8].

k = 3 (Absorption of fragments in the layer)

As in the case of k = 2, Refs [35, 33, 8] are correlated fully and Refs [35] and [32] partially.

k = 4 (Scattering in the chamber wall, the backing of the layer and the target structure)

Szabo [35] and White [33] used the same fission chamber, so these studies are fully correlated. Available information indicates that Ref. [8] may also have used the same chamber as Ref. [33], but since we do not have completely reliable information on this point we ascribe a partial correlation to Refs [33] and [8]. Thus Ref. [35] also partially correlated with Ref. [8].

k = 5 (Neutron attenuation in air)

No correlations were found in this partial error.

k = 6 (Neutron flux determination)

References [21, 26, 20, 29, 3-5] correlate fully because in all the experiments they describe a ^{10}B chamber was used to determine the neutron flux. In Ref. [30] the neutron flux was determined simultaneously by means of ^{10}B and ^{6}Li chambers. For this reason, all the above studies should correlate partially with Ref. [30].

In another group of studies [24, 25, 27, 6, 7] ^{6}Li was used to determine the neutron flux, and these studies therefore correlate fully with each other and partially with Ref. [30]. We consider that the group of studies using ^{10}B and the group using ^{6}Li do not correlate with each other.

In a third group of studies [33, 31, 12] the neutron flux was determined in relation to the scattering cross-section on hydrogen. All these studies correlate fully with each other. Besides, in Ref. [35] the neutron flux was determined not only by the recoil neutron method but by two others - by the Mn bath and by the associated particle methods. As a result, Ref. [35] correlates partially with Refs [33, 31, 12].

Studies [32] and [8] used identical methods of neutron flux determination and consequently correlate fully. In these studies, two of the three methods of neutron flux determination (the Mn bath and the associated particle methods) gave results agreeing with the methods of Ref. [35]. For this reason, we may consider that Ref. [35] correlates with Refs [32] and [8] with a factor $K_{6,\,35,\,32} = K_{6,\,35,\,8} = 0.7$.

k = 7 (background of the experiment)

No correlations.

k = 8 (Efficiency of fission recording)

No correlations were detected.

k = 9 (Uncertainty in the geometric factor)

No correlations were detected.

k = 10 (Cross-section of hydrogen (standard))

In Refs [12, 31, 33, 35-39] the hydrogen cross-section was used as the standard. All these studies correlate fully with each other.

k = 11 (Statistical error)

No correlations exist.

k = 12 (Error in normalization)

We renormalized Refs [17, 3, 6, 7] to the fission integral in the 0.1-1 keV region and at the thermal point. The normalization errors for these studies correlate fully. References [24] and [25] are normalized to the same fission integral, from 0.1 to 1 keV, and therefore correlate fully. The relative measurements of Refs [26, 20, 27, 21, 29, 5] were also normalized to the fission integral from 0.1 to 1 keV and are therefore fully correlated. Above 10 keV the data of Ref. [30] were renormalized to the data of Ref. [17] in the 2-10 keV region. The data of Ref. [17] were in turn normalized to the fission integral in the 0.1-1 keV region. For this reason, Ref. [30] correlates fully with all the above studies. References [4, 31] were renormalized to the integral from 10 to 30 keV, which was obtained from Refs [3, 6]. Hence it follows that Refs [4, 31] are ultimately also normalized to the integral from 0.1 to 1 keV and at the thermal point. Finally, as a result of our normalization Refs [3-7, 17, 20, 21, 24-27, 29-31] correlate fully with each other. Besides, the study of Poenitz [34] correlates fully with that of Czirr et al. [37] since the latter was normalized to the data of Ref. [34].

As has been pointed out above (see k = 1), the correlations between Ref. [12] and Refs [33, 10, 11] were transferred to k = 1. This correlation occurs because we renormalized the data of Ref. [12] to the weighted mean from Refs [10, 11, 33]. The correlation in question, $K_{12,\,33,\,12} = K_{12,\,10,\,12} = K_{12,\,11,\,12} = 0.3$, can also be left in k = 12 since the normalization error is zero for the "absolute" studies [10, 11, 33].

Table 2.1 gives optimized "weights" calculated by the computer program for cases of no correlation (K = 0); that is, the "weights" are inversely proportional to the square of the total error in the experiment, to the ascribed correlation according to (K) as above, and to the full correlation (K = 1) between the partial errors of the experiments for all energy intervals considered. These optimized "weights" for the different experiments were obtained by solving the system of equations in expression (1.7).

It will be seen from Table 2.1 that, as a result of analysis of the partial errors of the experiments and their correlations in the 0.1-1 keV region, the "weight" of the experimental data of De Saussure et al. [17], Czirr et al [6], Wasson [7] and partially of the data of Gwin et al. [3] (in the 0.6-1.0 keV region) has been increased and the "weight" of the data of Blons [26], Perez et al.[29]

and Michaudon et al. [20] has been reduced because they must be regarded as relative data strongly correlated with other data. In the 1-30 keV region the weight of the same data of De Saussure et al. [17], Gwin et al. [3], Wasson [7] and Gwin et al [6] was raised and the weight of the data of Refs [20, 26, 29] and Gaither [4] was lowered.

In the region above 30 keV the "weight" of the time-of-flight measurements is reduced, particularly the data of Gwin et al. [3] and Gaither [4], while the weight of the data of Szabo et al. [32], White [33], Poenitz [34] and the absolute data of Davis et al. [9] is increased. The data of Szabo et al. [35] undergo a sharp decrease in "weight" because of their strong correlation with Refs [32] and [33] and for all practical purposes need not be used in the evaluation. It would be very difficult however to confirm this before performing the calculations and even more to ignore them in the evaluation since the data are fairly accurate despite their correlation with several other studies.

In the 350-750 keV region the evaluated curve is determined by the data of Szabo et al. [32], White [33] and Poenitz [34], which are assigned approximately equal weights. In the region above 750 keV the "weights" of the experimental data from Refs [9, 32-34, 36] remained practically unchanged.

Tables 2.2-2.4 give coefficients of correlation between the energy intervals B_{nm} calculated by formula (1.11) for cases of no correlation between errors, ascribed correlations and full correlations.

Table 2.5 presents the values of $\sigma_f(^{235}U)$ evaluated by the above method and the evaluation errors, with and without allowance for correlations, for the optimal "weights". The errors in the evaluated curve given for energies above 30 keV represent the mean for the correlation intervals given in Table 2.2.

As will be seen from Table 2.5, the magnitude of the error depends quite strongly on the degree of correlation. Thus, the errors in an evaluated value obtained with allowance for correlations in the region up to 30 keV, are approximately twice as large as those obtained without allowance for correlations.

If one uses non-optimized "weights" - quantities inversely proportional to the error squares - the error in the evaluated value of $\sigma_f(^{235}U)$ is 10% higher on average than the errors indicated in Table 2.5 for the case of ascribed correlations (K) in the region up to 100 keV and 5% higher on average in the region up to 14 MeV.

The errors quoted in Table 2.5 for the evaluated value of $\sigma_f(^{235}U)$ with allowance for correlations in the energy region below 30 keV are 3-4%, and this figure may be regarded as the attained accuracy.

In the energy region above 30 keV the chosen energy intervals are too wide; as a result a large number of studies are evaluated in each interval, and this may lead to an incorrect evaluation of the error owing to non-uniform distribution of the experimental points of individual studies within the interval. For this reason, the errors above 30 keV indicated in Table 2.5 are merely illustrative in character. Analysis of the errors of experimental data in this region and the degree of agreement of the data suggest that in the 30 keV-15 MeV region the attained accuracy may be ± 3%.

Comparison of the evaluated data of the present study with the ENDF/B-V data [40] shows that they agree to within 1-3% in the 0.1 keV-15 MeV region.

In future measurements it will be necessary to devote attention to the 0.25-0.7 MeV and 14-20 MeV regions in order to resolve the discrepancies in experimental data existing in those regions and also to bring out the structure in the region above 100 keV. It may prove worth while to carry out experiments with lower accuracy if they clearly do not correlate with other existing experiments. Calculations by the method described in section 1 can be of help in the planning of new experiments as a means of finding the optimum methods of measuring particular parameters, so that the evaluated error obtained from the aggregate of all existing work plus the planned experiment is kept to a minimum.

3. EVALUATION OF $\alpha(^{235}U)$ IN THE 0.1-1000 keV REGION WITH ALLOWANCE FOR CORRELATIONS BETWEEN THE ERRORS OF DIFFERENT EXPERIMENTS

Existing measurements of $\alpha(^{235}U)$ [3, 17, 29, 41-54] show poor agreement with each other, differing in some cases by a factor of 1.5.

Experimental disagreement may be due to the following cases:

(a) Not all the experiments have been normalized consistently;

(b) Errors in some experiments have not been fully evaluated;

(c) Errors exist in the experimental methods of measurement.

Essentially all the available measurements of α in the region below 20 keV are relative since the instrument constants are determined by normalization to "reference" parameters; the quantities which serve as reference parameters are α for the resolved resonances [44], σ_f, σ_a and α in the thermal region [3, 21, 52], the fission and capture integrals in various energy regions [29, 42] and α at 30 keV [50, 51]. In Refs [46-49] an absolute measurement of α was performed by means of a scintillation tank with cadmium or gadolinium, and this made it possible to renormalize the data of Bandl et al. [50] and Vorotnikov et al. [51] at 30 ± 10 keV to a weighted mean value of α $(0.372 + 0.035)$.

It is difficult to evaluate how real the errors indicated by the authors are. In some energy intervals the scatter between the data is greater than the experimental errors cited by the authors.

A measurement of α consists in measuring the number of fissions N_f and the number of captures $N\gamma$. The signal-to-background ratio is higher for N_f than for N_γ, which means that uncertainties in the N_γ background cause larger errors in α than uncertainties in the N_f background. Values of σ_f can be obtained from the measurements of N_f, and, since the background is small, the results of different experiments should be in good agreement. If any experiment is at variance with the general trend in σ_f, this suggests that there may be errors in the background measurement which will also probably affect the measurement of N_f.

Such a comparison of the values of σ_f for ^{235}U does not, however, serve the purpose, because only in four experiments [3, 17, 21, 29] do the authors give σ_f values which are on the whole in satisfactory agreement with each other and with the results of other authors. In Refs [41, 43, 44] no σ_f values are given. In Refs [50, 51] no direct measurements of σ_f were performed (N_f was measured for a thick sample in Ref. [50]). Besides, the results of some experiments, for example those of Kurov et al. [44], have very poor sensitivity to the "σ_f criterion" but are on the other hand highly sensitive to scattered neutrons.

Thus σ_f measurement results would appear to give us no justification for reducing the "weight" of the experimental data under consideration.

A comparison of experimental methods of measuring $\alpha(^{235}U)$ indicates, first of all, that they have different sensitivities (number of instrument constants). The most sensitive methods are those used by Muradyan et al. [43], Kurov et al. [44] and Van Shi-di et al. [21]; less sensitive is the method of De Saussure et al. [17] and Perez et al. [29]; and the methods used by Czirr and Lindsey [41], Bandl et al. [50] and Vorotnikov et al. [51] have the lowest sensitivity.

It will be reasonable to analyse possible systematic errors in the different experiments with respect to four factors - the operation of gamma-ray and fission detectors, background determination and energy resolution.

Gamma-ray detectors should be insensitive to changes in the spectrum of capture and fission gamma-rays and to the total fission gamma energy. Czirr and Lindsey used a modified Moxon-Rae detector with a very low ratio of fission efficiencies to capture efficiencies $\varepsilon_f/\varepsilon_\gamma$ equal to 0.86 (expected value ~ 1.0-1.3). The Moxon-Rae detectors used have a scatter of the $\varepsilon_f/\varepsilon_\gamma$ ratios from 0.8 to 1.5. Since it is not known which value is correct, and since these total energy detectors may be sensitive to changes in the fission and capture gamma spectra as the recording threshold is raised, the weight of the experimental data of Czirr and Lindsey was reduced by adding a 5% error (quadratically).

The liquid scintillators used in Refs [17, 21, 29, 44] are normally more sensitive to changes in the capture gamma spectrum than the Moxon-Rae detectors; consequently, in the experiment of Kurov et al. [44], which relied on coincidences between the two halves of the detectors, the efficiency of the detector system may not be constant throughout the neutron energy region under study. In the experiments of Muradyan et al. and Vorotnikov et al. there may also be some sensitivity to changes in the spectrum of capture and fission gamma-rays.

The methods used for recording fission events N_f are imperfect as regards possible sensitivity to changes in the characteristics of the fission process as a function of incident neutron energy. However, the errors due to this effect are evidently not significant at energies below 30 keV. These changes in the fission process can be associated with a growth of **p**-interactions (at 5 keV ~ 25% of the fissions are due to p-neutrons). In principle there may be an additional error in experiments where the value of α depends on $\bar{\nu}$ if $\bar{\nu}$ varies as a function of the compound nucleus spin. This applies to the experiments of Czirr and Lindsey, Kurov et al., Van Shi-di et al., Bandl et al. and Vorotnikov et al. An additional 3% uncertainty was introduced owing to this effect.

There may be errors connected with the effects of self-shielding and multiple scattering. Gwin et al. have shown that a sample with a thickness of ~ 5.9×10^{-4} atoms/b gives a ~ 2% error in the average cross-section in the resonance region owing to multiple scattering. In the experiments of Refs [17, 21, 41, 43, 44] the samples were thinner than the sample of Gwin, so that the effects considered are insignificant. In Ref. [29], corrections have been made for these effects.

The most serious error in the measurement of α is associated with the determination of background. In order to analyse the background, we need to know the components which are time-dependent and those which are not time-dependent and also the rate of change of the background. Unfortunately, such information was not available on every experiment.

If the background was determined with resonance filters, measurements at energies above that of the filter are obviously unreliable and should be assigned a lower "weight". For this reason, the measurements of Czirr and Lindsey [41] in the region above 3 keV should be assigned a lower "weight" (the background was not measured above 2.8 keV). In the experiment of Muradyan et al. [43] it was difficult to measure the background, especially in the region above 900 eV, and the N_γ count was fairly low; so their results were also assigned a lower "weight".

In the experiments of Kurov et al. [44] and Van Shi-di et al. [21] we find high sensitivity to scattered neutrons, so that these data, too, have to be given a lower weight.

In the experiments of Bandl et al. and Vorotnikov et al. the largest errors in background determination occur in the region below 15 keV; in this region the authors cite large errors, which we did not alter.

Errors may occur in an experiment if delayed fission gamma rays are recorded as capture events. At energies below 30 keV these gamma rays can introduce an error of the order of ± 0.02 or less into the value of α [55]. This systematic error was considered by us in all experiments.

The value of α is given as the average over intervals of 100 eV in the region below 1 keV, over intervals of 1 keV in the 1-10 keV region and over intervals of 5 keV or more in the region above 10 keV. Since there is a structure in α, the energy resolution is important. The minimum number of resolution widths which fit into the averaging intervals should evidently be two (then ~ 12% of the reactions are caused by neutrons of a different energy). Therefore, the measurements of Czirr and Lindsey in the region above 5 keV were assigned a lower "weight" (at 5 keV $\Delta E \cong 5$ keV); the same thing applies to the measurements of Kurov et al. (at 5 keV $\Delta E \cong 0.59$ keV), Van Shi-di et al. (at 5 keV $\Delta E \cong 0.4$ keV), Bandl et al. in the region above 8 keV (at 8 keV $\Delta E = 0.4$ keV), and Vorotnikov et al. in the region above 10 keV (at 10 keV $\Delta E \cong 0.59$ keV)

The same procedure was adopted for the evaluation of $\alpha(^{235}U)$ as for $\sigma_f(^{235}U)$, i.e. a table was compiled for the partial errors of all α measurement experiments, correlations between the partial errors of the different experiments were brought to light, and a computer program was used to calculate optimum "weights" for the individual experiments which would minimize the error in the evaluated data by allowing for correlations.

Analysis of the methods and errors of the experiments revealed various correlations between their partial errors.

As regards $k = 1$ (energy-dependent background), the studies of Gwin et al. [3] and Perez et al. [29] were carried out on the same ORELA accelerator and may be correlated partially with respect to background. Similarly, a partial correlation should exist between the studies of Kurov et al. [44] and Van Shi-di et al. [21], since they performed their α measurements on a pulsed fast reactor.

For k = 2 (energy-dependent statistical errors) there are no correlations.

For k = 3 (error in normalization) the following correlations exist. The study of Gwin et al. [3] (normalized in the thermal energy region) correlates fully with studies [21] (normalization to α and σ_f at 2200 m/s in the thermal energy region), and [50] and [51] (both renormalized to the weighted mean α_{mean} at 30 ± 10 keV obtained with consideration of the data of Refs [3, 46-49]). The last-mentioned studies should correlate fully with each other and with Refs [21, 44, 50, 51], since the weighted mean α_{mean} used for normalization in other studies was obtained from them. References [3] and [44] correlate fully through Ref. [21] (the results of Ref. [44] are normalized in resonances for α obtained in Ref. [21]).

The experiment of De Saussure et al. [17] correlates fully with studies [29] (its results are normalized in the 100-200 eV region to the results of Ref. [17]), [41] (which used α in the 11.45-12.0 eV region taken from Ref. [3]) and [42] (where α measurements were normalized in the 200-1000 eV region to the data of Ref. [29]). In Ref. [44], the authors normalize the results to the value of α for 14 ^{235}U resonances without however indicating from where these data were taken. It may be assumed that they were taken either from Ref. [17] or, more probably, Ref. [21]. Therefore $K_{44,\ 21} \neq 1$, and in the case of Refs [17] and [44] a partial correlation is assumed.

Reference [52] should correlate fully with Refs [3] and [41] since we know that the value of α in the thermal region was used for calibration in Ref. [52]. There is however no specific information on the sources from where α_{therm} is taken, so that we have to ascribe only a partial correlation to these studies and to Refs [21] and [52].

For k = 4 (uncertainty in the relative neutron flux) studies [3, 17, 29, 41, 44, 46, 48, 49, 51] correlate fully with each other since all of them used a ^{10}B chamber for monitoring the neutron flux. Studies [3, 21, 42, 47] are correlated partially since Refs [42, 44, 47] do not mention the method of flux monitoring, and it can only be assumed that a ^{10}B counter was used as monitor. The experiments of Refs [3] and [43] are correlated partially since the latter used three counters - two with ^{10}B and one with NaI. Study [50] used a ^{6}Li counter and does not therefore correlate with any other study. As gold foils were employed in Ref. [45], it does not correlate with other studies either. In Ref. [52] a lead spectrometer was used, so there is no correlation with other studies.

For k = 5 (determination of the efficiency of the detector system), studies [17] and [29] correlate fully since the efficiency of the fission chamber was determined by fitting the data of Ref. [29] to those of Ref. [17] with respect to σ_γ in the 24-60 eV region. The efficiency of the tank for recording caputre, ε_γ, was determined by normalizing the data of Ref. [29] to those of Ref. [17] with respect to the capture integral in the 100-200 eV region, and the efficiency of the tank for recording fission events, ε_f, was obtained from the data of Ref. [17] based on the fission integral in the 100-200 eV region. The fact that efficiency was determined in Ref. [29] from the results of Ref. [17] has already been taken into account in our consideration of k = 3. References [46-49] correlate with each other since they used extrapolation of the pulse spectrum to zero. If we take into account that the magnitude of the extrapolation error depends little on the dimensions of the tank, which is the same only in Refs [46] and [48], these studies can be regarded as fully correlated. Besides, the normalization error in studies [50, 51] includes the error in determining the efficiency of the detector system. Correlations between studies [46-51] are taken into consideration for k = 3, but this is of little help because for k = 3 the magnitude of the error is given only in studies [50] and [51]. Accordingly it is better to assume full correlation between studies [46-51] for partial error k = 5, transferring the normalization error from k = 3 to k = 5 in advance and not attempting to assign a separate normalization error to studies [50] and [51].

The normalization error in Ref. [52] also includes the error in efficiency determination, since the recording efficiency of the detector system was determined in the experiment by means of calibration to the known value of α_{therm}; but in this case, although a partial error for k = 5 cannot be separated out, it is not logical to transfer the error from k = 3 because study [52] correlates for k = 3 with studies [17, 21, 41] and for all these studies both the normalization error and the error of efficiency determination are indicated. If the normalization error of Ref. [52] were divided arbitrarily, correlation could be assumed for both k = 3 and k = 5 (as in the case of Refs [17] and [29]). But in view of the lack of information we do not perform such a division and therefore leave the error in k = 3; thus for k = 5 Ref. [52] does not correlate with any other studies.

For k = 6 (the probability that a fission event will not be accompanied by the recording of fission neutrons), partial errors are found only in Refs [46-49]. References [46] and [48] are fully correlated since both used the same scintillation tank.

For k = 7 (uncertainty in ε_γ due to changes in the gamma-ray spectrum), Ref. [3] correlates fully with all experiments which used the same or a similar large liquid scintillation tank, i.e. Refs [3, 17, 29, 41, 21, 44, 46-49] correlate fully with each other.

For k = 8 (error in $\bar{\nu}$ leading to an uncertainty in α) three studies [41, 50, 51] are correlated with each other.

For k = 9 (error in the background due to delayed fission gamma-rays) it was considered that all experiments were correlated with each other.

For k = 10 (uncertainty in the weight of the sample and in the corrections for self-absorption in the layer) no correlations were found.

For k = 11 (uncertainty in corrections for impurity in the sample) Refs [46] and [48] correlate fully because they used the same sample having the same isotopic composition.

For k = 12 (neutron scattering in the sample and in the detector walls) Refs [17] and [29] correlate fully since they used the same method of making corrections for neutron scattering.

For k = 13 (energy resolution) no correlations were found.

Table 3.1 gives calculated "weights" for the $\alpha(^{235}U)$ values measured in each experiment in the cases of no correlations (K = 0), ascribed correlations (K) and full correlations (K = 1) between the errors of all studies for each energy interval. It will be seen that the analysis of partial errors in the experiments and consideration of the correlations between them increased the "weight" of the experimental data of Gwin et al. over almost the entire measured energy region from 0.1 to 100 keV and that of the data of De Saussure et al. [17] in the 0.1-3 keV region as the most accurate and independent measurements in this region. Also reliable are the results of Poletaev [49], the weight of which was increased in the 40-400 keV region. There was a decrease in the "weight" of the data of Perez et al. [29] in the 0.1-3 keV region (since they are relative data normalized to Ref. [17] and are therefore highly correlated with the latter), the data of Czirr et al. [41] in the 0.1-3.0 keV region owing to correlation with other studies in respect of normalization and neutron flux measurement, and also the data of Kurov et al. [44] and Van Shi-di et al. [21] in the 0.1-30.0 keV region as having large experimental errors and being strongly correlated in respect of a number of partial errors with other measurements.

The evaluated values of $\alpha(^{235}U)$ and the errors $\Delta\alpha_{ev}$ in each energy interval for the cases of no correlation and ascribed and full correlations are given in Table 3.2. The values of $\alpha(^{235}U)$ are in fact only very slightly dependent on the degree of correlation, the difference between the no correlation and full correlation cases amounting to no more than 3-5%. However, the size of the errors in the evaluated values of α changes very strongly - by a factor of 1.5-2. Thus, if correlations between the errors in experimental data are neglected, the error in α in the region up to 100 keV equals 3-5% and increases to 5-8.5% if the correlations described above exist. In the ~ 1 MeV energy region this difference between the errors is smoothed out owing to the small number of measurements and the very slight degree of correlation between them.

The above results on errors in α were obtained with optimized "weights", i.e. "weights which minimize the error in the evaluated value. Comparison of the cases of optimized and non-optimized weights (i.e. weights inversely proportional to the squares of the errors) shows that the errors $\Delta\alpha_{ev}$ coincide in the absence of correlation, as would be expected; in the case of the correlations ascribed by us the errors do not differ significantly (1-7%), but in the case of full correlation the difference is 20-30%. Therefore, in a real situation, if one is performing an evaluation with experiments that are correlated not fully but partially, one must first take into account correlations between the partial errors of the experiments and apply "weights" which allow for these correlations. For limited correlations, the "weights" themselves can be taken without optimization.

4. EVALUATION OF $\alpha(^{239}\mathrm{Pu})$ IN THE 0.1-1000 keV REGION WITH ALLOWANCE FOR CORRELATIONS BETWEEN THE ERRORS OF DIFFERENT EXPERIMENTS

During the last few years a number of experiments have been performed to measure $\alpha(^{239}\mathrm{Pu})$ and our knowledge of the value of α has considerably improved [3, 41, 44, 46, 47, 49, 50, 54, 56-67]. All these measurements differ in point of experimental technique and normalization procedure. The reference values used were the values of α for a number of well-resolved resonances [44, 58, 61, 67], the values of the fission and absorption cross-sections in the 0.05-0.4 eV region [3, 56], and values of α for thermal neutrons [59, 64, 66] and at 30 keV [50, 65]. In some studies part of the instrument constants were measured experimentally [46, 47, 49, 54, 62].

In normalizing the measurements it is necessary to take into account the dependence of the detector system efficiency on neutron energy. The gamma ray detectors used in the experiments should not be sensitive to changes in the spectra of capture and fission gamma rays or to the total fission gamma energy. There may be doubts on this point about experiments employing NaI and stilbene crystals of small volume [50, 59, 65, 67] and in cases where large liquid scintillators are used in the coincidence regime [28, 44]. Certain apprehensions arise also about independence from total gamma ray energy when Moxon-Rae type detectors are used [41, 58, 61] because in three different experiments they have different efficiency ratios for fission and capture.

The method of recording fission is not perfect since it can be sensitive to possible changes in the characteristics of the fission process as a function of incident neutron energy. Thus, the fission chamber may be sensitive to changes in the angular distributions of fission fragments in the energy range where p-interactions are important. However, the errors due to this effect are generally insignificant at energies below 30 keV.

In experiments where fission events are recorded on the basis of fission neutrons [41, 44, 46, 47, 49, 54, 58-60, 62], there may be sensitivity to changes in $\bar{\nu}$ with incident neutron energy, which will be greatest if small-volume detectors are used [41, 58, 59, 65-67], as is noted in Ref. [68], where the efficiency of recording fission is proportional to $\bar{\nu}$ and variations in $\bar{\nu}$ have a direct influence on the α measurement result.

Generally speaking, serious errors are possible in cross-section measurements owing to self-absorption and to multiple scattering effects. All the α measurements except those of Farrell et al. [61] and Kurov et al. [44] employed a single sample, which had an acceptable thickness ($\sim 10^{-3}$ atom/b). Farrell et al. made a correction for self-shielding whereas Kurov et al. did not make any such corrections in the region above 100 eV; consequently the "weight" of these latter measurements has to be reduced.

The most serious errors in α determination are those associated with background measurement. It is especially difficult to determine a background which varies as a function of the time of flight. The generally accepted method of background measurement with the help of black resonance filters does not give a sufficiently reliable measurement of a variable background. Some comments may be made on the determination of the "weight" of experiments in relation to a particular method of background measurement. Extrapolation of the measured background to an energy twice that of the filter is probably satisfactory, but at higher energies the measurements should be given a lower "weight". Accordingly, the measurements of Czirr et al. [41] and Belyaev et al. [59] were assigned a lower "weight" at energies above 6 keV. In the experiment of Schomberg et al. [58] in the 0.8–5.0 keV region large errors were observed in the determination of background, and therefore we ascribed a lower "weight" to these measurements in this energy region.

The data of Farrell et al. [61] in the region above 10 keV should also be considered to have a lower "weight" because the errors due to subtraction of the large fission background are high and, besides, the experiment had an additional background due to the aluminium container of the sample at higher energies.

Additional errors may occur in the experiment if delayed fission gamma rays are recorded as capture events. Walton and Sund [69] have shown that in the case of ^{239}Pu, isomers with half-lives of 3 to 80 μs are produced in 3.2% of fission events. The total energy of the gamma rays generated during isomer decay is lower than 2 MeV. It would seem that the most serious influence these isomers have is on the formation (at high energies) of a time-dependent background in the gamma-ray detector. According to our evaluations, an error in α equal to or lower than ± 0.02 will be caused by delayed gamma rays at neutron energies below 30 keV. This effect should be carefully investigated in the high-accuracy measurements of α which are to be performed.

Consideration of the difference in energy resolution in the different experiments leads to a reduction in the "weight" of the results of Belyaev et al. [59], Kurov et al. [44] (220 ns/m) in the region from 400 eV to 1 keV and above 2 keV and Ryabov et al. [28], and Czirr et al. [41] from 5 to 10 keV.

In determining the "weights" of experimental data for the evaluation of α, a 5% error was added quadratically for each case commented on above - a procedure which in general changed the "weight" of the experiment only slightly. Analysis of the experimental methods and errors revealed a number of correlations. The total experimental error in α was divided into 13 independent partial errors.

For k = 1 (energy-dependent background), the experiments of Gwin et al. [3] and Weston and Todd [57] can be partially correlated since they were performed on the same accelerator, which may be the source of an energy-dependent background. For the same reason, the data of Belyaev et al. [59], Bolotskij et al. [60,67] Ryabov et al. [28] and Kurov et al. [44] are also correlated with respect to background with a coefficient of 0.5.

For k = 2 (statistical errors), there are no correlations.

For k = 3 (error in normalization), the data of Gwin et al. [56] correlate with those of Refs [3, 57] (normalization in the thermal region), [58] (normalization to Ref. [56]), [41] (normalization using α at the thermal point), [60] (normalization to α values in resonances in the energy region below 50 eV obtained in Refs [28, 44, 56, 58, 59, 63]), [44] (normalization to α values in resonances obtained in Refs [28, 56, 57]), [28] (normalization to the same values of α as in Ref. [44]) and [63] (normalization to the α values in resonances obtained in Refs [44, 56, 58–60]). There is partial correlation for the data of Refs [56] and [59] (normalization to the thermal value of α obtained from the value of η measured in Ref. [59] and the value of ν at the thermal point) and Refs [56] and [61] (normalization to eight wide 0^+-resonances without indication of sources). The relative data of Bandl et al. [50] are correlated with the data of Refs [46, 47, 49] since we renormalized them to the weighted mean value of α at 30 ± 10 keV (0.318 ± 0.033) obtained from these studies. However, because of the absence of a partial error for k = 3 in Refs [46, 47, 49], it is more correct to transfer this correlation to k = 9 (determination of the efficiency of the detector system). Everything that has been said about Ref. [50] also applies to the work of Vorotnikov et al. [65]. For this reason, full correlation between Refs [50] and [65] is considered for k = 9 as well.

For k = 4 (background due to delayed fission gamma rays), we consider that the error is fully correlated in all experiments.

For k = 5 (uncertainty in the relative neutron flux), the data of Refs [3, 56, 57] are correlated fully through the cross-section of the $^{10}B(n,\alpha)$ reaction. The data of Refs [50, 58, 61] are correlated fully through the cross-section of the $^{6}Li(n,\alpha)$ reaction.

For k = 6 (neutron scattering in the sample and in the detector walls), the data of Refs [3] and [56] correlate fully since both studies used the same large liquid scintillator. References [59, 60, 67] can be correlated because they employed the same procedure and apparently the same apparatus.

For k = 7 (uncertainty in detector efficiency due to possible changes in the gamma-ray spectrum), we consider the error to be fully correlated in all experiments.

For k = 8 (error in $\bar{\nu}$ leading to an uncertainty in α), Refs [28, 41, 50, 57–60, 65, 67] are correlated fully.

For k = 9 (uncertainty in the efficiency of the detector system), Refs [3] and [56] use the same liquid scintillator and so correlate fully. References [46, 47, 49] contain the same error component due to uncertainty in the extrapolation of pulse distributions to the zero threshold and therefore correlate partially.

For k = 10 (change in the efficiency of the detector system with time), Refs [3] and [56] correlate fully as they use the same scintillation tank.

For k = 11 (uncertainty in the correction for impurities in the sample), k = 12 (probability that a fission event is not accompanied by the recording of fission neutrons) and k = 13 (energy resolution), no correlations were found.

The scheme described in Section 1 was used to calculate optimum "weights" to be assigned to the values of $\alpha(^{239}Pu)$ measured in each experiment for the cases of no correlation ($K = 0$), the above-determined correlations (K) and total correlation ($K = 1$). In the 0.1-6 keV region there was an almost twofold increase in the "weight" attached to the data of Gwin et al. [3] and Weston et al. [57]; this corresponds to the true picture, moreover, as these two experiments are most perfect from the point of view of up-to-date experimental techniques. They determined the evaluated values of α in this energy region (giving a sum of weights equal to 0.9). In the fairly narrow region from 6 to 10 keV the weight attached to the data of Gwin et al. [3] decreases somewhat because the partial error due to background (correlated by a coefficient of 0.5 with Ref. [57]) increases; and the data of Weston et al. [57] and Czirr et al. [41] determine the evaluated data in this region. In the 0.5-5.0 keV region there is a decrease in the weight attributed to the data from Refs [28, 44, 56, 58-60, 63, 67], but in the region above 5 keV the "weight" of these data does not change, although it remains small in absolute value (approximately an order of magnitude lower than the most accurate data). It is characteristic that in some intervals the "weight" of the data from Bergman et al. [64] increased by a factor of ~ 2 owing to the very small degree of correlation between this experiment and other data.

In the 10-100 keV region the evaluated α values are determined by the data of Gwin et al. [3], the "weight" of which increases up to 70 keV, Weston et al. [57], the "weight" of which is significant only up to 20 keV and then begins to decrease, and Poletaev et al. [49], the "weight" of which increases from 30 keV onward and is decisive in the second half of this interval.

In the region above 100 keV the evaluated values of α are determined by the absolute values of Poletaev et al. [49], Lottin et al. [46] and Hopkins et al. [47].

Table 4.1 gives the evaluated values of $\alpha(^{239}Pu)$ obtained by the method described in Section 1 and the evaluation errors for the cases of no correlation ($K = 0$) and ascribed (K) and full ($K = 1$) correlations. The evaluated α values themselves undergo practically no change as a function of the degree of correlation (changes not exceeding 2%); the errors in the 0.1-10 keV region amount to ~ 3% for $K = 0$, ~ 6% for the correlations mentioned in the text and ~ 7-10% for $K = 1$; in the 10-500 keV region the corresponding errors are ~ 5-9%, 8-11% and 12-16% for O, K and l values. Thus, it can be considered that the accuracy attained in the measurement of $\alpha(^{239}Pu)$ is 6% in the region from 0.1 to 20 keV, 8-10% from 20 to 100 keV, 13-17% from 100 to 800 keV and 25% from 0.8 to 1.0 MeV. The difference in the error $\Delta\alpha_{ev}$ for optimized and non-optimized "weights" is not more than 5-10% of the error value mentioned above, i.e. practically negligible.

Since the accuracy attained in measurements of $\alpha(^{239}Pu)$ does not yet match the accuracy required for reactor calculation (3.6% in the region below 100 keV and 5% in the region up to 0.8 MeV), further measurements of α are needed by methods which do not correlate with the existing ones.

5. EVALUATION OF $\sigma_f(^{239}Pu)$ IN THE 0.1 keV-15 MeV ENERGY REGION WITH ALLOWANCE FOR CORRELATIONS

The experimental data on $\sigma_f(^{239}Pu)$ were divided for this analysis into five groups. The first group included data obtained by the time-of-flight method with good resolution [3, 26, 28, 56, 58, 61, 70-74]. The data on $\sigma_f(^{239}Pu)$ obtained with monoenergetic sources in the 10 keV-15 MeV region were divided into four groups - absolute data (in the measurement of $\sigma_f(^{239}Pu)$ no data other than the well-known standard cross-sections of H(n,n), $^{10}B(n,\alpha)$ and σ_f at 2200 m/s were used) [32, 35, 75-77]; relative data (in the normalization of $\sigma_f(^{239}Pu)$ the authors used values of $\sigma_f(^{235}U)$ or $\sigma_f(^{238}U)$ at only one energy above thermal) [78, 79]; "derived"data (in simultaneous measurements of the ratio $\sigma_f(^{239}Pu)/\sigma_f(^{235}U)$ and of $\sigma_f(^{235}U)$ at common energies, it is possible to obtain $\sigma_f(^{239}Pu)$) [33, 80-83]; and direct data for the ratio $\sigma_f(^{239}Pu)/\sigma_f(^{235}U)$ (data obtained by the direct method and not containing any assumption regarding the shape of the energy dependence of $\sigma_f(^{235}U)$ or $\sigma_f(^{239}Pu)$) [84-88].

The following sequence was adopted for the evaluation of $\sigma_f(^{239}Pu)$:

(a) Tables of partial errors for all σ_f measurements (including relative measurements) were compiled;

(b) Correlations between the partial errors of the different experiments were brought to light;

(c) The above method of calculating the errors in evaluated data with allowance for correlations was applied;

(d) The results were processed by the PREDA program in the region above 30 keV, where measurements are available for the most part only at individual points; processing was separate for the absolute data on $\sigma_f(^{239}Pu)$ and for the ratios $\sigma_f(^{239}Pu)/\sigma_f(^{235}U)$, so as to obtain from these a value of $\sigma_f(^{235}U)$, which could then be compared with the fission cross-section for ^{235}U evaluated in Section 2, with a view to achieving consistency in the values of $\sigma_f(^{239}Pu)$, $\sigma_f(^{239}Pu)/\sigma_f(^{235}U)$ and $\sigma_f(^{235}U)$.

Analysing the experimental data we could distinguish 12 partial errors making up the total error and reveal a number of correlations between experiments.

$\underline{k = 1}$ (Determination of the number of ^{239}Pu nuclei) - Refs [32, 35, 75] are fully correlated since they represent a series of experiments carried out in different years by the same authors. They used the same ^{239}Pu layer. Reference [80] used the same fission chamber as Ref. [35]; however, these two are not fully correlated because, unlike the absolute measurements of $\sigma_f(^{239}Pu)$ [35], the ratio $\sigma_f(^{239}Pu)/\sigma_f(^{235}U)$ was measured in Ref. [80], while $\sigma_f(^{235}U)$ was measured absolutely in Ref. [33] with the use of the same layer. Thus, Refs [35] and [80, 33] correlate partially.

$\underline{k = 2}$ (Extrapolation of the fragment spectrum to the zero discrimination level) - Refs [32, 35, 75] correlate fully while Ref. [35] correlates partially with Refs [80] and [33] for the above reasons.

$\underline{k = 3}$ (Absorption of fragments in the layer) - the correlations are the same as those for k = 2.

$\underline{k = 4}$ (Scattering in the chamber walls, in the backing of the layer and in the target structure) - Refs [35] and [80] correlate fully since they used the same fission chamber. Correlation also exists between Refs [32] and [75]. However, since they do not contain measurements in the common energy region, they should be regarded as uncorrelated.

$\underline{k = 5}$ (Neutron attenuation in air) - Refs [35] and [32] are correlated fully (the experiments were performed at the same facility), as are Refs [35] and [75], in the common region from 800 to 972 keV.

k = 6 (Determination of neutron flux) - Refs [3, 28, 56, 58, 70, 71, 73, 74] are fully correlated **through** the cross-sections of the $^{10}B(n,\alpha)$ reaction, and Refs [35] and [32] only in the 800-972 keV region (at two energy points).

k = 7 (Background of the experiment) - Refs [61] and [72] can be considered to be correlated partially with respect to background since an underground nuclear explosion was used in both for cross-section measurements; Refs [35] and [32] and Refs [35] and [75] are correlated fully in their common energy region.

k = 8 (Efficiency of recording fission) - there is full correlation between Refs [61] and [72], where exactly the same method was used for recording fragments.

k = 9 (Uncertainty in the geometrical factor) - no correlations were found.

k = 10 (Cross-section of the standard (hydrogen)) - Refs [35] and [32] correlate fully since both use the same chamber, differing only for K = 4; there is full correlation between Refs [35, 80] and [82] since Ref. [82] correlates with Ref. [35] through the standard - hydrogen cross-section - and with Ref. [80] in the 0.5-1 MeV region through the standard $\sigma_f(^{235}U)$.

k = 11 (Statistical errors) - no correlations exist.

k = 12 (Error in normalization) - Refs [3, 28, 56, 58, 71, 73, 74] are correlated fully because the results of Refs [56] and [3] are normalized at the thermal point, those of Ref. [58] to the data of Refs [56] and [73], those of Ref. [71] to the data of Ref. [73], i.e. at the thermal point, and the results of Ref. [28] are also normalized at the thermal point. Reference [74] is normalized to the evaluation of Sowerby et al. [89] in the 10-30 keV region, i.e. to the data of Refs [56, 61, 72, 73], which determine the absolute value in the 0.1-1.0 keV region, and to the data of Refs [58, 70] and [71], used by Sowerby et al. in addition to the first four studies for the determination of the shape of the σ_f curve in the region below 30 keV. References [82-88, 79] are correlated fully since they used the $\sigma_f(^{235}U)$ value from our evaluation as the standard.

Calculation of the "weights" to be assigned to the measured $\sigma_f(^{239}Pu)$ values where there are correlations between the partial errors of the different experiments indicates that the "weight" of the experimental data undergoes practically no change in the 0.1-1 keV region, while in the 1-10 keV region the "weight" of the data from Refs [30, 70] increased by a factor of 1.5-2 and that of the data from Refs [28, 58, 61, 71, 74] decreased by a factor of ~ 2; in the 10-30 keV region there was some increase (~ 10-15%) in the "weights" of the data from Refs [3, 32, 58, 85, 86], which determine the evaluated data in this energy region, and an ~ 20% decrease in the "weight" of the data from Refs [61, 70, 71]. In the energy region above 30 keV the "weight" of the data changed little, the greatest "weight" being given to the absolute measurement from Refs [3, 32, 35, 75] and the measurements of the ratio, first of all in Ref. [88] and then in Refs [81, 85, 86, 90].

The errors in $\sigma_f(^{239}Pu)$ are 2.2-2.8% in the 0.1-30 keV region with allowance for correlations (1.5-2.4% without considering correlations) and ~ 3.5-4.0% in the energy region up to 10 MeV. The evaluated $\sigma_f(^{239}Pu)$ data and $\sigma_f(^{239}Pu)/\sigma_f(^{235}U)$ ratios, together with the earlier evaluated $\sigma_f(^{235}U)$ data, form a set of data which are in agreement to within 1.3%. Table 5.1 gives the evaluated values of $\sigma_f(^{239}Pu)$.

6. MATRICES OF THE COEFFICIENTS OF CORRELATION BETWEEN THE ERRORS OF GROUP CONSTANTS FOR $\sigma_f(^{235}U)$, $\sigma_f(^{239}Pu)$, $\alpha(^{235}U)$ and $\alpha(^{239}Pu)$

Several approaches to the determination of the covariant matrix of the group constants can be found in the literature [91, 92]. Dragt et al. [91] have calculated the uncertainties in group cross-sections for fission fragment capture, basing their work on the average resonance parameters and their errors and taking into account some degree of correlation between the data for different isotopes. Bazazyants et al. [92] present calculations of correlation coefficients for $\sigma_f(^{235}U)$ group constants in the region above 2 keV and of the covariant matrix of the group capture cross-sections for ^{238}U in a uranium-plutonium medium in the 0.4-200 keV region, obtained on the basis of the sensitivities of blocked group constants to the average resonance parameters.

Usachev and Bobkov [93] have developed a method of refining evaluated nuclear constants using the data of integral experiments on critical assemblies. The input data are the evaluated constants, their errors and the coefficients of correlation between them. Since the method described in Ref. [93] has been applied in a computer program [94] for group approximation of a reactor calculation, the evaluated constants, their errors and the coefficients $B_{n.m}$ have to be given in a standard group representation. These quantities can be calculated successively by the method described in Section 1.

The procedure for obtaining group constants from evaluated data is well known [95]. Therefore, we shall only describe the method of evaluating the errors in the group constants and the coefficients of correlation between them.

The error in an evaluated group constant is determined in the group in the following manner:

$$\Delta\sigma_n = \int\limits_{\Delta E_n} \Delta\sigma(E) f(E) dE ,$$

where f(E) is the "weight" function according to which the averaging is performed. It is assumed that function f(E) is so normalized that the integral over the group E_n equals

$$\int\limits_{\Delta E_n} f(E) dE = 1 . \qquad (6.1)$$

The root-mean-square error in the group is determined in the following manner:

$$\overline{|\Delta\sigma_n|^2} = \int\limits_{\Delta E_n} \int\limits_{\Delta E_n} \overline{\Delta\sigma(E)\Delta\sigma(E')}\, f(E) f(E') dE dE' =$$
$$= \int\limits_{\Delta E_n} \int\limits_{\Delta E_n} \sqrt{\overline{|\Delta\sigma(E)|^2}} \cdot \sqrt{\overline{|\Delta\sigma(E')|^2}} \cdot K_{E,E'} f(E) f(E') dE dE' , \qquad (6.2)$$

where $K_{E,E'}$ is the coefficient of correlation between the errors in the evaluated values at points E and E', and $\sqrt{\overline{|\Delta\sigma(E)|^2}}$ the root-mean-square error at point E. The above values, with allowance for correlations between the errors in the experimental data used in the evaluation, can be obtained by the method described in Section 1.

The coefficient of correlation between the errors of any two evaluated points n and m by definition takes the form

$$B_{nm} = \frac{\overline{\Delta\sigma_n \Delta\sigma_m}}{\sqrt{\overline{|\Delta\sigma_n|^2}} \cdot \sqrt{\overline{|\Delta\sigma_m|^2}}} \qquad (6.3)$$

Since the denominator of this formula is determined by expression (6.2), we have to find only the numerator:

$$\overline{\Delta\sigma_n \Delta\sigma_m} = \int\limits_{\Delta E_n} \int\limits_{\Delta E_m} \overline{\Delta\sigma(E)\Delta\sigma(E')}\ f(E)f(E')dEdE' =$$
$$= \int\limits_{\Delta E_n} \int\limits_{\Delta E_m} \sqrt{\overline{|\Delta\sigma(E)|^2}} \cdot \sqrt{\overline{|\Delta\sigma(E')|^2}} \cdot K_{EE'} \cdot f(E)f(E')dEdE' . \qquad (6.4)$$

Formulae (6.2), (6.3) and (6.4) were used to calculate the errors in the group constants and the coefficients of correlation between the errors. The evaluated values, their errors and the correlations between the errors were obtained earlier and described in the preceding sections.

The calculations for $\alpha(^{235}U)$, $\alpha(^{239}Pu)$, $\sigma_f(^{235}U)$ and $\sigma_f(^{239}Pu)$ were performed with a computer program. The relative accuracy of integration in the calculations was 10%, which is higher than the accuracy with which the errors and correlation coefficients were determined. The evaluated errors of the group constants and correlation coefficients differ by less than 10% in averaging over 1/E and E = const. spectra, which is less than the error introduced by the input data.

Tables 6.1–6.4 give the correlation matrices of the errors for $\alpha(^{235}U)$, $\alpha(^{239}Pu)$, $\sigma_f(^{235}U)$ and $\sigma_f(^{239}Pu)$ and the group constants for σ_f and σ_γ.

The values of $\sigma_f(^{235}U)$, $\alpha(^{235}U)$, $\sigma_f(^{239}Pu)$ and $\alpha(^{239}Pu)$ evaluated in this study have been included in the third version of the Soviet evaluated nuclear data library for ^{235}U and ^{239}Pu (BOYaD-3). The evaluated $\sigma_f(^{235}U)$ and $\sigma_f(^{239}Pu)$ values were discussed at a meeting of the specialist group on fission and recommended for use.

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Table 2.1

Optimized values of "weights" for different experiments in the cases of no correlation (K = 0), ascribed correlation (K) and full correlation (K = 1)

Authors	E , keV 0,I - 0,3			0,3 - 0,4			0,4 - 0,6			0,6 - 0,8			0,8 - I,0		
	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I
/ I7 /De Saussure	0,III	0,I50	0,000	0,I5I	0,206	0,000	0,I2I	0,223	0,000	0,I88	0,380	0,705	0,I97	0,432	0,705
/ 26 /Blons	0,093	0,000	0,000	0,I27	0,000	0,000	0,I02	0,000	0,000	0,I58	0,000	0,000	0,I65	0,000	0,000
/ 24 /Lemley	0,040	0,039	0,000	0,055	0,000	0,000	0,044	0,0I0	0,000	0,068	0,098	0,000	0,063	0,098	0,000
/ 20 /Michaudon	0,045	0,000	0,000	0,062	0,000	0,000	0,050	0,000	0,000	0,077	0,000	0,000	0,08I	0,000	0,000
/ 25 /Brown	0,03I	0,00I	0,000	0,009	0,000	0,000	0,033	0,000	0,000	0,060	0,062	0,000	0,057	0,064	0,000
/ 27 /Patrick	0,042	0,000	0,000	0,058	0,000	0,000	0,046	0,000	0,000	0,072	0,000	0,000	0,070	0,000	0,000
/ 2I /Van Shi-di	0,032	0,000	0,000	0,043	0,000	0,000	0,034	0,000	0,000	0,054	0,000	0,000	0,049	0,000	0,000
/ 29 /Perez	0,087	0,000	0,000	0,II9	0,000	0,000	0,095	0,000	0,000	0,I48	0,I09	0,000	0,I35	0,004	0,000
/ 3 / Gwin	0,09I	0,000	0,000	0,I40	0,II0	0,000	0,II2	0,026	0,000	0,I75	0,35I	0,295	0,I83	0,402	0,295
/ 5 / Mostovoya	0,066	0,000	0,000	-	-	-	-	-	-	-	-	-	-	-	-
/ 6 / Czirr	0,I74	0,267	0,378	0,236	0,684	I,0	0,I90	0,396	0,666	-	-	-	-	-	
/ 7 / Wasson	0,I88	0,543	0,622	-	-	-	0,I73	0,345	0,334	-	-	-	-	-	-

Authors	E , keV 1 - 2			2 - 4			4 - 5			5 - I0			I0 - 20		
	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I
/ I7 /De Saussure	0,I09	0,202	0,000	0,I52	0,4I5	0,705	0,I29	0,253	0,000	0,I29	0,353	0,425	-	-	-
/ 26 /Blons	0,09I	0,000	0,000	0.I28	0,0I3	0,000	0,I08	0,000	0,000	0,I00	0,000	0,000	0,088	0,004	0,000
/ 24 /Lemley	0,035	0,000	0,000	0,048	0,097	0,000	0,04I	0,0I5	0,000	0,046	0,I2I	0,000	0,062	0,000	0,000
/ 20 /Michaudon	0,045	0.000	0,000	0,063	0,006	0,000	0,053	0,000	0,000	0,049	0,000	0,000	-	-	-
/ 25 /Brown	0,032	0,000	0,000	0,044	0,064	0,000	0,038	0,037	0,000	0,038	0,05I	0,000	-	-	-
/ 27 /Patrick	0,039	0.000	0,000	0,054	0.007	0,000	0,046	0,000	0,000	0,053	0,006	0,000	0,074	0.000	0,000
/ 2I /Van Shi-di	0.027	0,000	0,000	0,054	0,000	0,000	0,032	0,000	0,000	0,03I	0,000	0,000	-	-	-
/ 29 /Perez	0,075	0.000	0,000	0.I04	0,000	0,000	0,088	0,000	0,000	0,I05	0,072	0,000	-	-	-
/ 3 / Gwin	0.I0I	0.II8	0,000	0,I4I	0,398	0.295	0,I20	0,224	0,000	0,I3I	0,342	0,544	0,I6I	0,274	0,000
/ 4 / Gaither	0,049	0,000	0,000	0,069	0,000	0,000	0,058	0,000	0,000	0,079	0,000	0,000	0.II3	0.000	0,000
/ 5 / Mostovaya	0,060	0,000	0,000	0,086	0.000	0,000	0.07I	0,000	0,000	0,084	0,000	0,000	-	-	-
/ 6 / Czirr	0,I69	0.340	0,500	-	0,000	0,000	-	0,000	0,000	-	-	-	0.279	0,722	I,00
/ 7 / Wasson	0,I69	0,340	0,500	-	-	-	0.I68	0,47I	I,000	-	-	-	-	-	-
/ 30 / Perez	-	-	-	0,057	0,000	0,000	0,048	0,000	0,000	0,057	0,000	0,000	0,075	0,000	0,000
/ 3I / Wasson	-	-	-	-	-	-	-	-	-	0,083	0,055	0,03I	0.I48	0,0	0,0

Table 2.1 (continued)

Authors	E ,keV														
	20 - 30			30 - II0			II0 - 350			350 - 750			750 - I500		
	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I
/ 26 / Blons	0,09I	0,040	0,000	-	-	-	-	-	-	-	-	-	-	-	-
/ 24 / Lemley	0,064	0,000	0,000	0,024	0,000	0,000	-	-	-	-	-	-	-	-	-
/ 27 / Patrick	0,076	0,000	0,000	-	-	-	-	-	-	-	-	-	-	-	-
/ 30 / Perez	0,08I	0,000	0,000	0,025	0,000	0,000	-	-	-	-	-	-	-	-	-
/ 3 / Gwin	0,I67	0,306	0,000	0,043	0,026	0,000	0,030	0,000	0,000	-	-	-	-	-	-
/ 4 / Gaither	0,II7	0,000	0,000	0,044	0,005	0,000	0,033	0,00I	0,000	0,037	0,050	0,000	0,017	0,0I5	0,000
/ 35 / Szabo	-	0,000	0,000	0,I58	0,0I3	0,000	0,077	0,003	0,000	0,I9I	0,048	0,304	0,083	0,025	0,000
/ 32 / Szabo	-	-	-	0,2I6	0,3I5	0,80I	0,I69	0,I87	0,0	0,I7I	0,2I3	0,0	0,082	0,087	0,000
/ 33 / White	-	-	-	0,I93	0,282	0,I00	0,I84	0,203	0,I58	0,2I4	0,268	0,5I8	0,I09	0,II6	0,000
/ 34 / Poenitz	-	-	-	0,I75	0,255	0,003	0,I36	0,I50	0,0	0,I63	0,203	0,I32	0,077	0,082	0,000
/ 38 / Käppeler	-	-	-	-	-	-	-	-	-	0,I24	0,I54	0,046	0,074	0,079	0,000
/ 39 / Diven	-			-	-	-	-	-	-	0,030	0,037	0,000	0,0I4	0,0I5	0,000
/ 6 / Czirr	0,254	0,654	I,000	0,068	0,I00	0,000	0,024	0,027	0,000	0,0I9	0,023	0,000	-	-	-
/ 3I / Wasson	0,I50	0,000	0,000	0,054	0,004	0,096	0,046	0,050	0,034	0,05I	0,004	0,000	0,023	0,024	0,000
/ 9 / Davis	-	-	-	-	-	-	0,30I	0,379	0,808	-	-	-	0,I60	0,I7I	0,000
/ I2 / Leugers	-	-	-	-	-	-	-	-	-	-	-	-	0,0I0	0,0I2	0,000
/ 36 / Barton	-	-	-	-	-	-	-	-	-	-	-	-	0,283	0,302	0,899
/ 37 / Czirr	-	-	-	-	-	-	-	-	-	-	-	-	0,068	0,072	0,I0I

Authors	E ,MeV																	
	I,5 - 3,0			3,0 - 5,0			5,0 - I2,0			I2 - I4			I4,I - I5			I5 - 20		
	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I
/ 32 / Szabo	0,I50	0,I65	0,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
/ 33 / White	0,084	0,092	0,000	-	-	-	0,I59	0,I33	0,000	0,2I8	0,226	0,I79	0,256	0,256	0,220	-	-	-
/ 34 / Poenitz	0,093	0,I02	0,000	0,I76	0,I83	0,000	-	-	-	-	-	-	-	-	-	-	-	-
/ 39 / Diven	0,0I7	0,0I9	0,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
/ 36 / Barton	0,489	0,536	0,948	0,5I7	0,538	0,876	0,528	0,575	0,876	-	-	-	-	-	-	-	-	-
/ 37 / Czirr	0,080	0,077	0,052	0,I50	0,I56	0,I20	0,I53	0,I67	0,I20	0,II4	0,II8	0,2I0	-	-	-	0,860	0,875	0,956
/ 8 / Szabo	0,068	0,009	0,000	0,III	0,II5	0,004	0,II2	0,I22	0,004	-	-	-	-	-	-	-	-	-
/ I2 / Leugers	0,0I9	0,000	0,000	0,046	0,008	0,000	0,048	0,003	0,000	0,035	0,000	0,000	-	-	-	0,I40	0,I25	0,044
/ I0 / Cance	-	-	-	-	-	-	-	-	-	0,333	0,345	0,6II	0,39I	0,39I	0,753	-	-	-
/ II / Alkhazov	-	-	-	-	-	-	-	-	-	0,300	0,3II	0,000	0,353	0,353	0,027	-	-	-

Table 2.2

Matrix of coefficients of correlation between energy intervals $B_{n,m}$ without correlations between errors

n,m	I	2	3	4	5	6	7	8	9	I0	II	I2	I3	I4	I5	I6	I7	I8	I9	20	2I
I	I,00	0,84	0,95	0,74	0,74	0,96	0,73	0,83	0,68	0,5I	0,50	0,I8	0,09	0,04	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2		I,00	0,90	0,86	0,85	0,83	0,76	0,69	0,70	0,62	0,6I	0,22	0,I2	0,05	0,00	0,00	0,00	0,00	0,00	0,00	0,00
3			I,00	0,80	0,80	0,94	0,70	0,8I	0,65	0,55	0,54	0,20	0,I0	0,04	0,00	0,00	0,00	0,00	0,00	0,00	0,00
4				I,00	I,00	0,74	0,88	0,8I	0,82	0,40	0,4I	0,I2	0,06	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
5					I,00	0,74	0,88	0,8I	0,82	0,4I	0,42	0,I2	0,07	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
6						I,00	0,79	0,88	0,74	0,59	0,58	0,23	0,I4	0,08	0,03	0,00	0,00	0,00	0,00	0,00	0,00
7							I,00	0,9I	0,94	0,5I	0,52	0,20	0,II	0,05	0,03	0,00	0,00	0,00	0,00	0,00	0,00
8								I,00	0,86	0,47	0,48	0,I8	0,I0	0,05	0,03	0,00	0,00	0,00	0,00	0,00	0,00
9									I,00	0,70	0,64	0,27	0,I6	0,I3	0,08	0,00	0,00	0,00	0,00	0,00	0,00
I0										I,00	0,99	0,45	0,28	0,2I	0,I0	0,00	0,00	0,00	0,00	0,00	0,00
II											I,00	0,45	0,28	0,2I	0,I0	0,00	0,00	0,00	0,00	0,00	0,00
I2												I,00	0,80	0,85	0,53	0,42	0,I8	0,I7	0,I9	0,2I	0,00
I3													I,00	0,7I	0,67	0,39	0,I5	0,I8	0,I8	0,20	0,00
I4														I,00	0,65	0,42	0,I7	0,I8	0,20	0,22	0,00
I5															I,00	0,7I	0,62	0,64	0,26	0,I6	0,27
I6																I,00	0,82	0,82	0,25	0,I4	0,30
I7																	I,00	0,83	0,I7	0,00	0,42
I8																		I,00	0,35	0,I9	0,43
I9																			I,00	0,92	0,37
20																				I,00	0,00
2I																					I,00

n,m		n,m		n,m	
I	0,I - 0,3 keV	8	4,0 - 5,0 keV	I5	0,75 - I,5 MeV
2	0,3 - 0,4 keV	9	5,0 -I0,0 keV	I6	I,5 - 3,0 MeV
3	0,4 - 0,6 keV	I0	I0,0 -30,0 keV	I7	3,0 - 5,0 MeV
4	0,6 - 0,8 keV	II	20,0 -30,0 keV	I8	5,0 -I2,0 MeV
5	0,8 - I,0 keV	I2	30,0 -II0 keV	I9	I2,0 -I4,0 MeV
6	I,0 - 2,0 keV	I3	II0 -350 keV	20	I4,I -I5,0 MeV
7	2,0 - 4,0 keV	I4	350 -750 keV	2I	I5,0 -20,0 MeV

Table 2.3

Matrix of coefficients of correlation between energy intervals $B_{n,m}$
for the case of ascribed correlations between errors

n,m	I	2	3	4	5	6	7	8	9	I0	II	I2	I3	I4	I5	I6	I7	I8	I9	20	2I
I	I,00	0.92	0.98	0,83	0,80	0.97	0,8I	0,94	0,82	0,85	0,83	0,29	0,27	0,25	0,I8	0,00	0,00	0,00	0,00	0,00	0,00
2		I,00	0.96	0,87	0,86	0,97	0,86	0,89	0,87	0,96	0,95	0,34	0,28	0,27	0,I8	0,00	0,00	0,00	0.00	0,00	0,00
3			I,00	0,86	0.84	0,99	0,84	0,95	0,85	0,90	0,88	0.3I	0,28	0.26	0,I8	0,00	0,00	0,00	0,00	0,00	0,00
4				I,00	I,00	0,89	I,00	0.9I	0,90	0,83	0,83	0,28	0.23	0,24	0,17	0,00	0,00	0,00	0,00	0,00	0,00
5					I,00	0,88	I.00	0,90	0,99	0,82	0,82	0,27	0,22	0,24	0,I7	0,00	0,00	0,00	0.00	0,00	0,00
6						I,00	0.88	0,96	0.88	0,92	0,9I	0,32	0.28	0,26	0.18	0,00	0,00	0,00	0,00	0,00	0,00
7							I,00	0,9I	0,99	0,83	0,83	0,28	0,22	0,24	0,17	0,00	0,00	0,00	0,00	0,00	0,00
8								I,00	0.90	0,84	0.83	0,29	0,25	0,24	0,18	0,00	0,00	0.00	0,00	0,00	0,00
9									I.00	0,83	0,83	0,29	0,23	0,26	0,I8	0,0I	0,00	0,0I	0,0I	0,0I	0,0I
I0										I,00	0,98	0.35	0,28	0,27	0,I6	0,00	0,00	0,00	0.00	0,00	0,00
II											I,00	0,34	0,27	0,26	0,I7	0,00	0,00	0,00	0,00	0,00	0,00
I2												I,00	0,77	0,89	0,59	0,60	0,37	0,33	0,27	0,28	0.I4
I3													I,00	0,7I	0,7I	0,48	0,30	0.28	0,22	0,23	0.I2
I4														I,00	0,70	0,62	0,37	0,36	0,29	0,30	0.I6
I5															I,00	0,82	0,68	0,73	0,37	0,28	0.4I
I6																I,00	0,84	0,84	0,32	0,23	0.39
I7																	I,00	0,87	0,25	0,I0	0,43
I8																		I,00	0,37	0,24	0,5I
I9																			I,00	0.94	0,45
20																				I.00	0.I5
2I																					I,00

Table 2.4

Matrix of coefficients of correlation between energy intervals $B_{n,m}$ for the case of full correlation between errors

n,m	I	2	3	4	5	6	7	8	9	I0	II	I2	I3	I4	I5	I6	I7	I8	I9	20	2I
I	I,00	0,93	0,98	0,83	0,88	0,98	0,88	0,96	0,86	0,90	0,88	0,56	0,47	0,5I	0,64	0,58	0,64	0,64	0,70	0,39	0,93
2		I,00	0,98	0,94	0,94	0,98	0,94	0,87	0,93	0,99	0,96	0,68	0,52	0,62	0,55	0,50	0,55	0,55	0,72	0,44	0,88
3			I,00	0,95	0,95	0,I0	0,95	0,95	0,93	0,97	0,95	0,68	0,55	0,62	0,64	0,57	0,64	0,64	0,75	0,46	0,94
4				I,00	I,00	0,93	I,00	0,9I	0,99	0,96	0,95	0,83	0,74	0,74	0,73	0,64	0,75	0,75	0,83	0,60	0,92
5					I,00	0,93	I,00	0,9I	0,99	0,96	0,95	0,83	0,74	0,74	0,73	0,64	0,75	0,75	0,83	0,60	0,92
6						I,00	0,93	0,95	0,92	0,96	0,94	0,66	0,52	0,6I	0,64	0,59	0,64	0,64	0,74	0,44	0,93
7							I,00	0,9I	0,99	0,96	0,95	0,83	0,74	0,74	0,73	0,64	0,75	0,75	0,83	0,60	0,92
8								I,00	0,89	0,88	0,86	0,68	0,6I	0,60	0,77	0,69	0,79	0,79	0,76	0,48	0,97
9									I,00	0,96	0,94	0,83	0,73	0,74	0,72	0,64	0,74	0,74	0,8I	0,58	0,90
I0										I,00	0,97	0,77	0,59	0,70	0,6I	0,54	0,6I	0,6I	0,75	0,50	0,88
II											I,00	0,8I	0,63	0,75	0,64	0,59	0,63	0,63	0,85	0,64	0,83
I2												I,00	0,87	0,96	0,77	0,74	0,78	0,78	0,87	0,84	0,62
I3													I,00	0,8I	0,83	0,76	0,85	0,85	0,76	0,73	0,57
I4														I,00	0,79	0,8I	0,76	0,75	0,85	0,86	0,49
I5															I,00	0,97	0,99	0,99	0,8I	0,72	0,66
I6																I,00	0,93	0,93	0,79	0,74	0,54
I7																	I,00	I,00	0,8I	0,70	0,70
I8																		I,00	0,8I	0,70	0,70
I9																			I,00	0,92	0,68
20																				I,00	0,36
2I																					I,00

Table 2.5

Evaluated values of $\sigma_f(^{235}U)$ and errors in the evaluated data, with and without consideration of correlations for optimal "weights"

Energy, keV	$\sigma_f(^{235}U)$, b	Errors $\Delta\sigma_f$,%		
		K=0	K	K=I
I	2	3	4	5
0,I - 0,2	20,7I	I,44	3,08	3,22
0,2 - 0,3	20,I9			
0,3 - 0,4	I2,88	I,68	3,24	3,44
0,4 - 0,5	I3,34	I,50	3,I6	3,39
0,5 - 0,6	I4,69			
0,6 - 0,7	II,20	I,87	3,70	4,27
0,7 - 0,8	I0,80			
0,8 - 0,9	7,92	I,9I	3,7I	4,27
0,9 - I,0	7,34			
I,0 - 2,0	7,I0	I,42	3,I5	3,39
2,0 - 3,0	5,27	I,68	3,7I	4,27
3,0 - 4,0	4,73			
4,0 - 5,0	4,I5	I,55	3,35	3,80
5,0 - 6,0	3,70	I,69	3,94	4,58
6,0 - 7,0	3,3I			
7,0 - 8,0	3,26			
8,0 - 9,0	2,89			
9,0 - I0	3,03			
I0 - 20	2,44	2,02	3,56	3,82
20 - 30	2,I0	2,05	3,70	4,07
30 - 40	2,00	I,25	I,57	2,65
40 - 50	I,9I5			
50 - 60	I,823			
60 - 70	I,749			
70 - 80	I,677			
80 - 90	I,6I7			
90 - I00	I,575			
I00	I,555	I,II	I,25	I,99
II0	I,545			

Table 2.5 (continued)

I	2	3	4	5
I20	I,522			
I30	I,50I			
I40	I,478			
I50	I,458			
I60	I,438			
I70	I,4I9			
I80	I,399			
I90	I,380			
200	I,366			
220	I,336			
240	I,3II			
260	I,289			
280	I,270			
300	I,250			
320	I,233			
340	I,22I			
360	I,2I5	I,2I	I,45	2,57
380	I,2I4			
400	I,2I2			
450	I,I9I			
500	I,I66			
550	I,I46			
600	I,I28			
650	I,II3			
700	I,I05			
750	I,I04	0,83	I,00	I,53
800	I,II7			
850	I,I44			
900	I,I70			
950	I,204			
I000	I,2I5			
I,I MeV	I,220			
I,2	I,226			
I,4	I,239			

Table 2.5 (continued)

I	2	3	4	5
I,6	I,258	0,92	I,02	I,30
I,8	I,276			
2,0	I,284			
2,5	I,248			
3,0	I,205			
3,5	I,I77			
4,0	I,I47			
4,5	I,II7			
5,0	I,087	I,27	I,39	I,7I
5,5	I,052			
6,0	I,I39			
6,5	I,386			
7,0	I,600			
7,5	I,755			
8,0	I,820			
8,5	I,824			
9,0	I,8I2			
9,5	I,800			
I0,0	I,786			
II,0	I,770			
I2,0	I,768	I,I0	I,I3	I,73
I3,0	I,922			
I4,I	2,07I	3,40	3,43	3,64
I5,0	2,I08			

Table 3.1

Optimized "weights" of experiments in the cases of no correlation (K = 0) and ascribed (K) and full (K = 1) correlations

Authors	E, keV																	
	0,I - 0,2			0,2 - 0,3			0,3 - 0,4			0,4 - 0,5			0,5 - 0,6			0,6 - 0,7		
	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I
/3 /Gwin	0,289	0,443	I,000	0,269	0,368	I,000	0,270	0,370	I,000	0,29I	0,425	I,000	0,298	0,4I7	I,000	0,287	0,407	I,000
/I7 /De Saussure	0,250	0,382	0,000	0,234	0,202	0,000	0,225	0,I94	0,000	0,275	0,39I	0,000	0,263	0,369	0,000	0,26I	0,370	0,000
/29 /Perez	0,I98	0,000	0,000	0,I80	0.I56	0,000	0,I88	0,I62	0,000	0,I99	0,000	0,000	0,203	0,000	0,000	0,207	0.000	0,000
/4I /Czirr	0,I00	0,000	0,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
/42 /Corvi	-	-	-	0,III	0,096	0,000	0,II3	0,098	0,000	0,I2I	0,I55	0,000	0,I23	0,I72	0,000	0,I25	0,I77	0,000
/43 /Muradyan	0,095	0,I74	0,000	0,086	0,074	0,000	0,090	0,078	0,000	-	-	-	-	-	-	-	-	-
/44 /Kurov	0,056	0,000	0,000	0,05I	0,044	0,000	0,054	0,046	0,000	0,056	0,000	0,000	0,057	0,000	0,000	0,058	0,000	0,000
/2I /Van Shi-di	0,0I2	0,00I	0,000	0,025	0,02I	0,000	0,022	0,0I9	0,000	0,027	0,000	0,000	0,029	0,00I	0,000	0,033	0,00I	0,000
/52 /Bluhm	-	-	-	0,044	0,039	0,000	0,038	0,033	0,000	0,03I	0,029	0,000	0,027	0,04I	0,000	0,029	0,045	0,000

Authors	E, keV																	
	0,7 - 0,8			0,8 - 0,9			0,9 - I,0			I - 2			2 - 3			3 - 4		
	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I	K=0	K	K=1	K=0	K	K=I	K=0	K	K=I
/ 3 /Gwin	0,287	0,425	I,000	0,292	0,396	I,000	0,306	0,42I	I,000	0,238	0,357	0,000	0,I28	0,I54	0,000	0,289	0,338	0,055
/I7 /De Saussure	0,269	0,387	0,000	0,282	0,382	0,000	0,266	0,366	0,000	0,248	0,372	I,000	0,243	0,29I	0,537	-	-	-
/29 /Perez	0,207	0,002	0,000	0,2I9	0.000	0,000	0,224	0,008	0,000	0,I44	0,000	0,000	0.I43	0,034	0,000	0,326	0,4I3	0,649
/4I /Czirr	-	-	-	-	-	-	-	-	-	0,098	0,000	0,000	0,09I	0,022	0,000	0,256	0,I65	0,296
/42/ Corvi	0,II9	0,I55	0,000	0,I27	0,I72	0,000	0,I28	0,I76	0,000	0,II4	0,098	0,000	-	-	-	-	-	-
/43 /Muradyan	-	-		-	-		-	-	-	0,063	0,I3I	0,000	0,059	0,070	0,000	-	-	-
/44 /Kurov	0,056	0,000	0,000	0,0II	0;000	0,000	0,0I3	0,000	0,000	0,042	0,006	0,000	0,047	0,000	0,000	0,063	0,04I	0,000
/2I /Van Shi-di	0,034	0,004	0,000	0,036	0,00I	0,000	0,037	0,00I	0,000	0,03I	0,004	0,000	0,032	0,002	0,000	0,024	0,0I5	0,000
/52 /Bluhm	0,028	0,027	0,000	0,033	0,049	0,000	0,026	0,028	0,000	0,022	0,032	0,000	0,0I8	0,0I5	0,000	0,042	0,028	0,000
/45 /Dvukhsherstnov	-	-	-	-	-		-	-		-	-	-	0,239	0,4I2	0,463	-	-	-

Table 3.1 (continued)

Authors	E, keV																	
	4 - 5			5 - 6			6 - 7			7 - 8			8 - 9			9 - I0		
	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I
/ 3 /Gwin	0,394	0,507	0,862	0,406	0,496	I,000	0,260	0,257	0,003	0,42I	0,496	0,840	0,383	0,452	I,000	0,366	0,427	I,000
/ 29/Perez	0,297	0,336	0,I38	-	-	-	0,350	0,346	0,992	0,333	0,344	0,I60	0,I53	0,I73	0,000	0,267	0,337	0,000
/ 4I Czirr	0,I20	0,06I	0,000	0,26I	0,279	0,000	0,I36	0,I35	0,000	0,I00	0,065	0,000	0,I57	0,I27	0,000	0,II8	0,076	0,000
/ 44/Kurov	0,094	0,048	0,000	0,I42	0,096	0,000	0,092	0,09I	0,000	0,023	0,0I5	0,000	0,047	0,038	0,000	0,0I3	0,008	0,000
/ 2I/Van Shi-di	0,06I	0,03I	0,000	0,068	0,046	0,000	0,074	0,073	0,000	0,023	0,0I5	0,000	0,043	0,035	0,000	0,037	0,024	0,000
/ 5I/Vorotnikov	-	-	-	0,052	0,035	0,000	0,047	0,047	0,000	0,059	0,038	0,000	0,088	0,07I	0,000	0,083	0,053	0,000
/ 52/Bluhm	0,034	0,0I7	0,000	0,07I	0,048	0,000	0,04I	0,05I	0,000	0,04I	0,027	0,000	0,039	0,032	0,000	0,036	0,024	0,000
/ 50/Bandl	-	-	-	-	-	-	-	-	-	-	-	-	0,090	0,072	-	0,080	0,05I	-

Authors	E, keV																	
	I0 - 20			20 - 30			30 - 40			40 - 50			50 - 60			60 - 70		
	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I
/ 3 / Gwin	0,405	0,536	I,000	0,I7I	0,294	0,43I	0,220	0,520	0,454	0,I54	0,280	0,I93	0,I97	0,404	0,44I	0,283	0,432	0,470
/ 42/ Corvi	0,I68	0,24I	0,000	0,073	0,I9I	0,000	-	-	-	-	-	-	-	-	-	-	-	-
/ 44/ Kurov	0,062	0,032	0,000	0,04I	0,030	0,000	-	-	-	-	-	-	-	-	-	-	-	-
/ 2I/ Van Shi-di	0,048	0,025	0,000	0,023	0,0I6	0,000	-	-	-	-	-	-	-	-	-	-	-	-
/ 46/ Lottin	-	-	-	0,I47	0,I00	0,244	0,23I	0,I42	0,546	0,225	0,390	0,807	0,2I0	0,028	0,472	0,260	0,050	0,000
/ 47/ Hopkins	-	-	-	0,II9	0,08I	0,000	-	-	-	-	-	-	0,I82	0,265	0,000	-	-	-
/ 48/ Weston	-	-	-	0,085	0,058	0,000	0,I3I	0,08I	0,000	0,I58	0,000	0,000	0,II6	0,000	0,000	0,I63	0,03I	0,000
/ 49/ Poletaev	0,06I	0,032	0,000	0,I03	0,070	0,000	0,206	0,I27	0,000	0,228	0,320	0,000	0,207	0,303	0,087	0,294	0,487	0,530
/ 50/ Bandl	0,I02	0,053	0,000	0,058	0,039	0,000	0,890	0,055	0,000	0,I05	0,0I0	0,000	0,088	0,000	0,000	-	-	-
/ 5I/ Vorotnikov	0,I54	0,08I	0,000	0,I80	0,I2I	0,325	0,I22	0,075	0,000	0,I30	0,000	0,000	-	-	-	-	-	-

Table 3.1 (continued)

Authors	E, keV																	
	70 - 80			90 - I00			I00 - 200			200			250			300		
	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I
/ 3 /Gwin	0,2I9	0,254	0,244	0,306	0,259	0,09I	0,044	0,040	0,000	-	-	-	-	-	-	-	-	-
/ 46/Lottin	0,284	0,234	0,000	-	-	-	-	-	-	0,7I8	0,994	I,000	-	-	-	0,440	0,654	I,000
/ 48/Weston	0,I78	0,I48	0,000	0,694	0,74I	0,909	0,I58	0,007	0,000	0,282	0,006	0,000	0,387	0,3II	0,000	0,234	0,000	0,000
/ 49/Poletaev	0,3I9	0,364	0,756	-	-	-	0,250	0,325	0,226	-	-	-	-	-	-	0,326	0,346	0,000
/ 45/Dvukhsherstnov	-	-	-	-	-	-	0,I44	0,294	0,I60	-	-	-	-	-	-	-	-	-
/ 47/Hopkins	-	-	-	-	-	-	0,260	0,334	0,6I4	-	-	-	0,6I3	0,689	I,000	-	-	-
/ 5I/Vorotnikov	-	0,000	0,000	-	-	-	0,I44	0,000	0,000	-	-	-	-	-	-	-	-	-

Authors	E, keV																	
	400			500			600			750			900			I000		
	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I	K=0	K	K=I
/ 46/ Lottin	0,3I8	0,3I4	0,767	0,585	0,664	0,992	0,425	0,473	0,050	-	-	-	-	-	-	-	-	-
/ 47/ Hopkins	0,30I	0,298	0,233	-	-	-	0,450	0,527	0,950	0,63I	0,689	I,000	0,624	0,654	I,000	0,66I	0,7I9	I,000
/ 48/ Weston	0,I60	0,I58	0,000	-	-	-	0,I25	0,000	0,000	-	-	-	-	-	-	-	-	-
/ 49/ Poletaev	0,22I	0,230	0,000	0,4I5	0,336	0,008	-	-	-	0,369	0,3II	0,000	0,376	0,346	0,000	0,339	0,28I	0,000

Table 3.2

Evaluated values of $\alpha(^{235}U)$ and the errors of evaluation with consideration of optimized weights in the cases of no correlation (K = 0) and ascribed (K) and full (K = 1) correlations

Interval No.	Energy keV	α ev.			Evaluation error, %		
		K=0	K	K=I	K=0	K	K=I
I	0,I - 0,2	0,6I	0,63	0,63	3,52	5,2I	6,54
2	0,2 - 0,3	0,47	0,46	0,46	3,36	5,25	6,48
3	0,3 - 0,4	0,52	0,52	0,52	3,43	5,3I	6,60
4	0,4 - 0,5	0,36	0,36	0,35	3,55	5,32	6,57
5	0,5 - 0,6	0,30	0,3I	0,29	3,57	5,37	6,55
6	0,6 - 0,7	0,4I	0,4I	0,42	3,59	5,4I	6,7I
7	0,7 - 0,8	0,43	0,44	0,45	3,57	5,38	6,67
8	0,8 - 0,9	0,50	0,52	0,5I	3,7I	5,44	6,86
9	0,9 - I,0	0,64	0,66	0,68	3,74	5,5I	6,76
I0	I - 2	0,40	0,43	0,43	3,48	5,30	6,98
II	2 - 3	0,39	0,4I	0,39	3,47	4,72	6,77
I2	3 - 4	0,34	0,34	0,30	5,23	7,24	8,84
I3	4 - 5	0,36	0,36	0,37	4,96	6,75	7,86
I4	5 - 6	0,34	0,34	0,38	7,05	8,65	II,00
I5	6 - 7	0,39	0,39	0.36	5,42	7,47	9,I7
I6	7 - 8	0,4I	0,4I	0,43	5,28	6,9I	8,I0
I7	8 - 9	0,45	0,46	0,5I	5,2I	7,22	8,43
I8	9 - I0	0,39	0,40	0,42	4,99	6,98	8,24
I9	I0 - I5	0,39	0,40	0,39	7,36	8,66	I2,06
20	I5 - 20	0,38	0,37	0,36	6,64	I0,I3	I2,69
2I	I0 - 20	0,40	0,40	0,40	5,3I	7,07	8,35
22	20 - 25	0,37	0,36	0,36	6,54	7,83	9,60
23	25 - 30	0,35	0,35	0,35	7,32	10,4I	I2,30
24	20 - 30	0,37	0,38	0,38	3,68	6,56	8,35
25	30 - 40	0,37	0,37	0,37	4,56	8,I4	8,84
26	40 - 50	0,35	0,35	0,35	4,69	8,25	9,30
27	50 - 60	0,33	0,32	0,32	4,30	7,58	8,75
28	60 - 70	0,3I	0,30	0,29	5,I3	7,96	8,70
29	70 - 80	0,3I	0,3I	0,29	5,32	8,40	9,I4
30	90 - I00	0,29	0,29	0,30	I0,4I	II,30	I2.40
3I	I00 - 200	0,24	0,23	0,23	5,25	7,52	I0,I3
32	200	0,23	0,25	0,25	8,46	9,99	9,99
33	250	0,20	0,20	0,2I	8,69	I0,I8	II,I0
34	300	0,20	0,2I	0,22	6,62	9,39	9,99
35	400	0,I6	0,I6	0,I6	5,87	9,II	I0,38
36	500	0,I6	0,I5	0,I5	7,95	9,68	I0,39
37	600	0,I3	0,I4	0,I4	7,37	9,49	I0,97
38	750	0,I3	0,I3	0,I3	8,54	9,75	I7,75
39	900	0,I0	0,I0	0,I0	9,74	I0,84	I2,34
40	I000	0,086	0,086	0,087	8,9I	II,27	I2,63

Table 4.1

Evaluated values of α(^{239}Pu) and the errors of evaluation with consideration of optimized weights in the cases of no correlation (K = 0) and ascribed (K) and full (K = 1) correlations

Interval No.	Energy keV	α_{eV}			Evaluation error, %		
		K=0	K	K=I	K=0	K	K=I
I	0,I - 0,2	0,857	0,853	0,87I	3,07	5.43	6,36
2	0,2 - 0,3	0,929	0,932	0,929	3,03	5,37	6,II
3	0,3 - 0,4	I,I6I	I,I27	I.I50	3,I6	5,5I	6,43
4	0,4 - 0,5	0,488	0,446	0,426	3,7I	5,64	6,33
5	0,5 - 0,6	0,728	0,7I7	0,7I8	3,30	5,56	6,40
6	0,6 - 0,7	I,524	I,553	I,488	3,I3	5,54.	6,44
7	0,7 - 0,8	0,962	0,932	0,890	3,I5	5,63	6,40
8	0,8 - 0,9	0,804	0,796	0,790	3,45	5,66	6,46
9	0,9 - I,0	0,7I7	0,693	0,675	3,47	5,56	6,36
I0	I - 2	0,886	0,849	0,802	3,38	6,05	7,I0
II	2 - 3	I,044	I,008	0,972	3,47	6,03	7,I5
I2	3 - 4	0,8I8	0,794	0,739	3,67	5,90	7,I8
I3	4 - 5	0,852	0,843	0,83I	3,56	5,92	7,22
I4	5 - 6	0,842	0,843	0,807	3,7I	6,I3	7,I9
I5	6 - 7	0,794	0,773	0,745	3,76	6,07	7,II
I6	7 - 8	0,642	0,640	0,642	3,82	6,26	II,90
I7	8 - 9	0,559	0,552	0,537	3,76	6,I6	II,57
I8	9 - I0	0,600	0,603	0,606	3,88	6,I2	II,85
I9	I0 -I5	0,5I5	0,5I8	0,447	6,53	8,33	I4,85
20	I5 - 20	0,446	0,445	0,4I9	7,27	8,84	I5,75
2I	I0 - 20	0,473	0,476	0,486	4,22	6,08	II,03
22	20 - 30	0,356	0,356	0,350	4,68	7,I6	I3,07
23	30 - 40	0,288	0,286	0,282	5,63	8,59	I2,38
24	40 - 50	0,256	0,257	0,243	5,66	8,42	I2,36
25	50 - 60	0,225	0,225	0,225	6,55	8,6I	I3,2I
26	60 - 70	0,I96	0,I97	0,I93	7,48	8,83	I3,00
27	70 - 80	0,I78	0,I77	0,I72	8,00	9,3I	I4,26
28	80 - 90	0,2I3	0,2I4	0,220	II,98	I3,67	I6,52
29	90 - I00	0,I49	0,I49	0,I45	I2,I2	I3,04	I9,56
30	I00 - 200	0,I4I	0,I4I	0,I39	8,45	9,82	I4,77
3I	250	0,I06	0,I06	0,I06	I6,74	I6,74	I6,74
32	300	0,II6	0,II6	0,II9	II,77	I3,08	I6,25
33	400	0,0852	0,0856	0,0890	9,45	II,17	I5,80
34	500	0,0784	0,078I	0,0690	I3,24	I4,54	I8,39
35	600	0,0558	0,056I	0,0650	I5,09	I5,83	20,66
36	750	0,0670	0,0674	0,0800	I6,70	I7,44	23,I2
37	900	0,0378	0,0378	0,0372	25,03	25,55	33,34
38	I000	0,0270	0,0270	0,0270	25,95	25,95	25,95

Table 5.1

Evaluated values of $\sigma_f(^{239}Pu)$

E, keV	$\frac{\sigma_f(^{239}Pu)}{\sigma_f(^{235}U)}$	$\sigma_f(^{239}Pu)$, b	E, MeV	$\frac{\sigma_f(^{239}Pu)}{\sigma_f(^{235}U)}$	$\sigma_f(^{239}Pu)$, b
1	2	3	4	5	6
0,I - 0,2		I8,22	0,25	I,I554	I,502
0,2 - 0,3		I7,50	0,30	I,2080	I,5I0
0,3 - 0,4		8,56	0,40	I,2822	I,554
0,4 - 0,5		9,46	0,50	I,36I9	I,588
0,5 - 0,6		I5,70	0,60	I,4I84	I,600
0,6 - 0,7		4,58	0,75	I,48I9	I,636
0,7 - 0,8		5,45	0,90	I,4458	I,706
0,8 - 0,9		5,I0	I,0	I,4230	I,729
0,9 - I,0		7,99	I,2	I,4943	I,832
I - 2		4,45	I,4	I,5464	I,9I6
2 - 3		3,3I	I,6	I,5476	I,947
3 - 4		3,05	I,8	I,5376	I,962
4 - 5		2,37	2,0	I,5296	I,964
5 - 6		2,35	2,5	I,5272	I,906
6 - 7		2,05	3,0	I,5386	I,854
7 - 8		2,II	3,5	I,5472	I,82I
8 - 9		2,20	4,0	I,5554	I,784
9 - I0		I,92	4,5	I,5685	I,752
I0 - 20	0,680	I,659	5,0	I,5823	I,720
20 - 30	0,738	I,550	5,5	I,6I4I	I,698
30 - 40	0,785	I,570	6,0	I,5540	I,770
40 - 50	0,826	I,582	6,5	I,4567	2,0I9
50 - 60	0,860	I,568	7,0	I,3500	2,I60
60 - 70	0,888	I,553	7,5	I,2650	2,220
70 - 80	0,9II	I,528	8,0	I,2396	2,256
80 - 90	0,932	I,507	8,5	I,2500	2,280
90 - I00	0,953	I,500	9,0	I,2655	2,293
I00	0,9697	I,508	9,5	I,2789	2,302
I20	0,99I5	I,509	I0,0	I,29I2	2,306
I40	I,0203	I,508	II,0	I,2893	2,282
I60	I,0473	I,506	I2,0	I,2557	2,220
I80	I,075I	I,504	I3,0	I,I8II	2,270
200	I,I000	I.503	I4,0	I,I294	2,330
			I5.0	I,II20	2.344

Table 6.1

Correlation matrix of errors in the value of $\alpha(^{235}U)$ and group constants for $\sigma_\gamma(^{235}U)$

E , keV	n	5	6	7	8	9	I0	II	I2	I3	I4	I5	I6	I7	$\Delta\alpha$, ev. %	$\sigma_\gamma(^{235}U)$, b
800 - I400	5	I,00													I0,57	0,I00
400 - 800	6	0,89	I,00												8,95	0,I64
200 - 400	7	0,79	0,98	I,00											9,02	0,263
I00 - 200	8	0,80	0,80	0,75	I,00										7,52	0,333
46,5- I00	9	0,65	0,84	0,87	0,7I	I,00									8,30	0,552
2I,5- 46,5	I0	0,63	0,82	0,84	0,69	0,98	I,00								7,40	0,732
I0- 2I,5	II	0,52	0,66	0,68	0,59	0,83	0,92	I,00							6,75	0,970
4,65- I0,0	I2	0,37	0,48	0,50	0,47	0,73	0,80	0,80	I,00						7,00	I,3I5
2,I5- 4,65	I3	0,33	0,42	0,44	0,48	0,65	0,7I	0,76	0,96	I,00					5,83	I,8I4
I,0 - 2,I5	I4	0,33	0,42	0,44	0,53	0,58	0,65	0,7I	0,8I	0,90	I,00				4,70	3,I22
0,465-I,0	I5	0,38	0,48	0,50	0,44	0,68	0,75	0,83	0,87	0,89	0,89	I,00			5,40	4,574
0,2I5-0,465	I6	0,38	0,48	0,50	0,44	0,66	0,73	0,80	0,84	0,88	0,94	0,97	I,00		5,20	7,500
0,I00-0,2I5	I7	0,38	0,49	0,50	0,44	0,66	0,7I	0,75	0,82	0,82	0,94	0,92	I,00	I,00	5,20	II,975

Table 6.2

Correlation matrix of errors in the value of $\alpha(^{239}Pu)$ and group constants for σ_γ (^{239}Pu)

E, keV	n	5	6	7	8	9	I0	II	I2	I3	I4	I5	I6	I7	$\Delta\alpha$ ev. %	σ_γ (^{239}Pu), b
800 - I400	5	I,00													20,63	0,047
400 - 800	6	0,84	I,00												I2,72	0,III
200 - 400	7	0,83	0,96	I,00											II,23	0,I63
I00 - 200	8	0,67	0,67	0,68	I,00										9,8I	0,2I3
46,5 - I00	9	0,25	0,46	0,45	0,8I	I,00									9,25	0,3II
2I,5 - 46,5	I0	0,32	0,59	0,59	0,76	0,94	I,00								7,53	0,484
I0 - 2I,5	II	0,25	0,44	0,46	0,73	0,87	0,92	I,00							6,35	0,834
4,65 - I0,0	I2	0,I5	0,26	0,29	0,60	0,7I	0,7I	0,88	I,00						5,92	I,572
2,I5 - 4,65	I3	0,I2	0,2I	0,23	0,60	0,70	0,66	0,83	0,98	I,00					5,90	2,709
I,0 - 2,I5	I4	0,II	0,20	0,22	0,57	0,65	0,62	0,82	0,97	0,98	I,00				6,00	4,478
0,465 - I,0	I5	0,I0	0,I9	0,2I	0,59	0,68	0,63	0,8I	0,95	0,99	0,98	I,00			5,57	6,85I
0,2I5 - 0,465	I6	0,I2	0,I9	0,2I	0,60	0,68	0,63	0,8I	0,94	0,98	0,96	I,00	I,00		5,67	II,3I6
0,I00 - 0,2I5	I7	0,I0	0,I9	0,2I	0,59	0,68	0,64	0,8I	0,92	0,96	0,94	0,99	I,00	I,00	5,65	I6,636

Table 6.3

Correlation matrix of errors and group constants for $\sigma_f(^{235}U)$

E, keV	n	I	2	3	4	5	6	7	8	9	I0	II	I2	I3	I4	I5	I6	I7	$\sigma_f(^{235}U)$, b
6500 - I0500	I	I,00																	I,672
4000 - 6500	2	0,99	I,00																I.II7
2500 - 4000	3	0,83	0,83	I,00															I.200
I400 - 2500	4	0,82	0,82	0,82	I,00														I,266
800 - I400	5	0,64	0,64	0.62	0,7I	I,00													I,205
400 - 800	6	0,I8	0,I8	0,I7	0,42	0,65	I,00												I,I46
200 - 400	7	0,I8	0,I8	0,I6	0,4I	0.66	0,79	I,00											I.274
I00 - 200	8	0,I8	0,I8	0,I5	0,39	0,67	0,7I	0,86	I,00										I,470
46,5 - I00	9	0.I7	0,I7	0,I8	0,42	0,53	0,68	0,82	0,80	I,00									I.7I8
2I,5 - 46,5	I0	0,08	0,08	0,09	0,2I	0,32	0,53	0,53	0,54	0,72	I,00								2,0II
I0 - 2I,5	II	0,00	0,00	0,00	0,00	0,I0	0,2I	0,24	0,28	0,45	0,72	I,00							2,444
4,65 - 10,0	I2	0,00	0,00	0,00	0,00	0,06	0,09	0,I2	0,I4	0,22	0,48	0,69	I,00						3,373
2,I5 - 4,65	I3	0,00	0,00	0,00	0,00	0,03	0,05	0,08	0,I5	0,I9	0,46	0.65	0,9I	I,00					4,862
I.0 - 2,I5	I4	0,00	0,00	0,00	0,00	0,03	0,06	0,09	0,I2	0,22	0,46	0,66	0,85	0,88	I,00				6.927
0,465- I,0	I5	0,00	0,00	0,00	0,00	0,00	0,03	0,06	0,09	0,I5	0,39	0,57	0.8I	0,83	0.82	I,00			II,I33
0.2I5- 0,465	I6	0,00	0,00	0,00	0,00	0,00	0,04	0,08	0,II	0,2I	0,49	0,70	0,77	0,80	0,82	0,87	I,00		I6,I43
0.100- 0,2I5	I7	0,00	0,00	0,00	0,00	0.00	0,04	0,06	0,09	0,I8	0,34	0,50	0,76	0,78	0,84	0,8I	0,90	I,00	20.578

Table 6.4

Correlation matrix of errors and group constants for $\sigma_f(^{239}Pu)$

E , keV	n	2	3	4	5	6	7	8	9	I0	I1	I2	I3	I4	I5	I6	I7	$\sigma_f(^{239}Pu)$ b
4000 - 6500	2	I,00																I,753
2500 - 4000	3	0,79	I,00															I,848
I400 - 2500	4	0,76	0,80	I,00														I,947
800 - I400	5	0,7I	0,72	0,88	I,00													I,774
400 - 800	6	0,73	0,58	0,74	0,93	I,00												1,599
200 - 400	7	0,70	0,54	0,72	0,90	0,94	I,00											I,5I4
I00 - 200	8	0,67	0,49	0,69	0,87	0,94	0,97	I,00										I,507
46,5- I00	9	0,70	0,52	0,64	0,84	0,90	0,94	0,96	I,00									I,54I
2I,5- 46,5	I0	0,70	0,52	0,64	0,84	0,90	0,94	0,96	0,99	I,00								I,562
I0,0 2I,5	I1	0,49	0,5I	0,48	0,68	0,68	0,70	0,72	0,73	0,73	I,00							I,643
4,65 I0,0	I2	0,II	0,I3	0,I0	0,36	0,37	0,40	0,44	0,44	0,44	0,80	I,00						2,I80
2,I5- 4,65	I3	0,00	0,00	0,00	0,I8	0,2I	0,25	0,28	0,26	0,26	0,68	0,86	I,00					3,00I
I,0 - 2,I5	I4	0,00	0,00	0,00	0,I8	0,2I	0,25	0,28	0,26	0,26	0,68	0,86	0,99	I,00				5,775
0,465- I,0	I5	0,00	0,00	0,00	0,I2	0,I5	0,20	0,26	0,24	0,24	0,59	0,80	0,9I	0,9I	I,00			8,540
0,2I5-0,465	I6	0,00	0,00	0,00	0,I2	0,I5	0,20	0,26	0,24	0,24	0,50	0,80	0,90	0,90	0,99	I,00		I2,35I
0,I00- 0,2I5	I7	0,00	0,00	0,00	0,I6	0,20	0,23	0,26	0,24	0,24	0,66	0,85	0,96	0,96	0,87	0,8I	I,00	I8,989